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From the Editors

In our final issue for the year we offer papers on a range of topics, originating in a variety of circumstances. Three of the articles—by O'Shea, Banks *et al.*, and Eipper—are the published versions of papers delivered at the FNCV Fauna Survey Group Seminar on reptiles and amphibians of Victoria, held in October 2016. The lead article, by Adair *et al.*, updates the plant census of an area within the Western Port region and reports the results of fieldwork conducted over a period of more than 30 years. The two Constributions are more narrow in focus but nonetheless interesting for that. Butler's study of germination in saltbush and Mather's detailing of the recent history of Lake Flannigan, like the other papers published here, add to our understanding and appreciation of the wider world of natural history studies.

The Editors take pleasure in providing our readers with a range of informative papers, to add to their Christmas reading lists.

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Front cover: Black Snakes *Pseudechis* emerging from recently-laid membranous sacs. Photo Scott Eipper.

A census and significance of the vascular flora of Mount Cannibal, Victoria

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Abstract
Mount Cannibal Flora and Fauna Reserve is a site of State significance located at the interface between the Highlands–Southern Fall and Gippsland Plains bioregions in the Western Port region, Victoria. A total of 281 species of native vascular plants and 84 exotic species are recorded from the reserve, including nine native species of State significance. A rich orchid flora (57 species), including one nationally threatened species, is present. The reserve is threatened by invasive high risk environmental weeds, particularly Berry-flower Heath *Erica baccans* and Sweet Pittosporum *Pittosporum undulatum*. A weed management program is critical to the long-term sustainability of biodiversity at Mt Cannibal. (*The Victorian Naturalist*, 134 (6), 2017, 160–176)

Keywords: Mt Cannibal, census, botanical survey, *Erica baccans*

Introduction

The Mount Cannibal Flora and Fauna Reserve (MCFFR) is a high quality block of native vegetation renowned for its geomorphology, botanical richness, recreational opportunities and scenery. The prominent rise of Mt Cannibal is a feature in the local landscape that attracts a regular stream of visitors throughout the year. Tonkinson (1995) provided the first detailed account of the flora of Mt Cannibal, although its botanical significance, based on limited data, was recognised earlier by Opie *et al.* (1984) in their survey of the Western Port region.

In this paper, we update the census of vascular plants recorded from Mt Cannibal and review the conservation status of the site and its floristic elements (Table 1). The taxonomy for this paper follows the online Flora of Victoria, 'VICFLORA' at http://data.rbg.vic.gov.au/vicflora/flora/ (Royal Botanic Gardens).

The study area

Mt Cannibal Flora and Fauna Reserve (38.0515°S, 145.6830°E) is located in the southern foothills of the Central Highlands of Victoria, approximately 4 km north of Garfield township and 18 km ENE of Pakenham. The reserve is approximately 53 ha in area and encompasses Mt Cannibal at 238 m ASL. The reserve is a remnant block of native vegetation surrounded predominantly by private land cleared for agriculture or low density urban development. The reserve is an outlier of native vegetation on the southern fringe of Bunyip State Park in the transition zone between the Highlands–Southern Fall and Gippsland Plains bioregions.

Climate

The site is located in the warm summer–cold winter zone of southern Australia, with rainfall (mean 600–1000 mm) occurring throughout the year, but predominantly in the winter and early spring. On average, the driest months are January, February and March. Winds are predominantly from the west, with southwest winds common from spring to autumn. Occasional heavy rainfall events over several days are mostly associated with east coast low pressure systems.

Landforms, geology and soils

The reserve occurs within the moderately dissected ridge and valley landscape unit of the Eastern Uplands (Earthresources 2016). The geomorphology of Mt Cannibal is of regional significance (Victorian Resources Online 2016). The geology consists of Upper Devonian intrusive granites and granodiorites of the Tynong formation and is one of the southernmost outcrops to display rock slabs and boulders. The soils belong to the Jindivick Association where the surface soils are dark brown-grey or grey sandy loams, or occasionally sandy

clay loams, with the sand fraction containing coarse angular sand and small gravel. At depths of about 20 cm, yellowish grey-brown or yellowish brown similar textured soils occur. Areas of greatest soil development are on lower slopes and plateaus, with the best examples occurring on lower western slopes where soils tend to be peaty. Drainage from the reserve predominantly flows into Cannibal Creek and ultimately Western Port (Sargeant 1975).

Land-use

The area in the vicinity of Mt Cannibal, and possibly parts of Mt Cannibal, were used for timber harvesting from the 1880s to the early 1990s. The Garfield North Road to the West of Mt Cannibal provided access to timber cutters. In the 1950s a section of the lower western slopes was cleared for cattle grazing and a small dam installed with surface drains to collect surface flows. However, grazing was soon abandoned due to poor pasture growth. In the 1970s, Mt Cannibal was acquired by local government for the protection of the natural landscape within the municipality of Pakenham. The MCFFR is currently managed by Cardinia Shire and assisted by the Friends of Mt Cannibal who have been active in MCFFR since 1992.

The MCFFR is almost surrounded by cleared land used for grazing on modified pastures and to a lesser degree cropping or perennial horticulture. Roadsides, private property and local watercourses support remnant vegetation and provide connections to neighbouring reserves, notably Bunyip State Park and Cannibal Creek Reserve.

Botanical surveys

In 1984, quadrat data from two sites was collected from Mt Cannibal in a survey of the vegetation of the Westernport region. The reserve was considered to be of regional significance due to its botanical integrity and occurrence of rare and interesting species and botanical communities (Opie *et al.* 1984). A detailed and comprehensive survey of the reserve occurred between 1995 and 1996 with nine site visits (Tonkinson 1995) where a total of 289 species of vascular plant (231 indigenous, 58 exotic) were recorded.

The Orchidaceae of Mt Cannibal was subject to special study between 2008 and 2013 by field naturalist David Piko, who listed and photographed 50 species. In 2015, a survey for high risk exotic species was completed (Adair 2015). Additional survey work was undertaken in autumn and spring 2016 to augment the records of previous authors and to resolve the identification of some species that presented taxonomic difficulties, or where they lacked fertile material.

Currently, 369 taxa of vascular plant have been recorded from MCFFR (284 indigenous and 85 exotic). The larger families represented are: Orchidaceae (56 indigenous species), Poaceae (25 species), Asteraceae (25 species) and Fabaceae (25 species).

Vegetation community classification and descriptions

Six broad vegetation types were recognised by Tonkinson (1995); with the exception of a small artificial wetland community, these vegetation types match well the five Ecological Vegetation Classes (EVC) mapped for the reserve (DELWP 2016):

Damp Heathy Woodland EVC 793 (Fig. 1)

This EVC is equivalent to the shrubland, heathy woodland/open-forest mapped and described by Tonkinson (1995), and the Silver-leaf Stringybark Damp Heathy Woodland (Community 15) of Brown (2005) and is found on the lower western slopes of MCFFR. Typically this vegetation type is a woodland with upper stratum to 10 m high with a dense heathy understorey that becomes tall scrub if long unburnt. Mealy Stringybark *Eucalyptus cephalocarpa*, Swamp Gum *E. ovata* and Narrow-leaf Peppermint *E. radiata* are the dominant upper stratum trees, particularly on the lower slopes of the reserve on soils with impeded drainage. On better drained soils, White Stringybark *E. globoidea* may also be present. Understorey shrubs are often dense and dominated by Prickly Tea-tree *Leptospermum continentale*, Silver Banksia *Banksia marginata*, and Common Cassinia *Cassinia aculeata*. The ground stratum vegetation is dominated by sedges, particularly Thatch Saw-sedge *Gahnia radula* and perennial grasses, forming a dense cover.

In the region, this vegetation community is widespread and extends along the base of foothills adjacent to mountain ranges (below 100 m altitude) with scattered remnants occurring

Fig. 1. Damp Heathy Woodland EVC 793.

Fig. 2. Blackthorn Scrub EVC 27.

in low-lying areas along the southern side of the Dandenong, Black Snake and Blue Ranges (Brown 2005).

Blackthorn Scrub EVC 27 (Fig. 2)
The vegetation type was described by Tonkinson (1995) as rock outcrop complex and by Brown (2005) as Sweet Bursaria Scrub Community 24. More generally it occurs on northerly and westerly slopes of mountains and valleys with a restricted distribution on exposed slopes and ridgelines of lower foothills towards the east (below 100 m altitude). In the local area, isolated remnants occur on lower slopes of the Black Snake Range. Typically this association is dominated by small trees and shrubs with a sparse ground stratum (DELWP 2016).

Soil development strongly influences the floristics of the Blackthorn Scrub at Mt Cannibal, where several associations are recognised. Where rock outcrops occur at the surface or intrusions shallowly below it and little soil is present, a lichen-moss-ephemeral herbfield develops. Run-off from the rock sheets provides moisture and seepage that enables this association to persist. In rock crevices where soil is deeper and rock fissures may occur, scattered trees and shrubs are present, including Green Scentbark *Eucalyptus fulgens*, although in very low numbers. As the soil becomes deeper, the ground stratum develops sparse grassland, or a shrubland with Dusty Miller *Spyridium parvifolium*, Twiggy Daisy-bush *Olearia ramulosa*, and Burgan *Kunzea ericoides sens. lat.* Nineteen regionally significant plant species are recorded from this EVC and its ecotone into Lowland Forest.

Herb-rich Foothill Forest EVC 23 (Fig. 3)
This EVC is included within the open forest of the south-west slopes described by Tonkinson (1995) and lowland forest communities of Brown (2005). It occurs on relatively fertile and moderately well drained soil with easterly and southerly aspects, mainly on lower slopes and gullies (DELWP 2016). The shrub stratum is sparse to medium and the ground stratum has a high cover and diversity of herbs and grasses.

Lowland Forest EVC 16 (Fig. 4)
This EVC is equivalent to the Open Forest vegetation type described by Tonkinson (1995) and the Messmate Lowland Forest Community (Community 7) and White Stringybark Lowland Forest (Community 8) of Brown (2005). It occurs widely within MCFFR on well-drained soils on the mid-slope regions to the east, west and south of Mt Cannibal. The structure and floristics within this vegetation type are variable. The upper canopy stratum may reach 25 m and is dominated by *E. globoidea*, *E. obliqua*, *E. radiata*, and Mountain Grey Gum *E. cypellocarpa*, with low frequencies of *E. cephalocarpa*. The understorey ranges from a sparse to dense shrub stratum, and a well-developed grass and herb-rich ground stratum. Grassy Lowland Forest with well-developed patches of Kangaroo Grass *Themeda triandra* is present in some areas, an association that is now infrequent in the Melbourne region. On the plateau near the

Fig. 3. Herb-rich Foothill Forest EVC 23.

Fig. 4. Lowland Forest EVC 16.

Fig. 5. Riparian Scrub/Swampy Riparian Woodland EVC 17.

summit of Mount Cannibal the lowland forest is dominated by *E. cypellocarpa* with a grassy understorey and a low frequency of shrubs. Indications of historical grazing and a long period since fire may account for low shrub abundance in this association. In the southern lookout area, which is less exposed to drying NW winds, mesic shrubs and grasses occur.

On the extensive eastern mid-slope area, the Lowland Forest is dominated by *E. globoidea*, *E. obliqua*, *E. radiata* and *E. cypellocarpa* with sparse to moderate shrub cover. This association is widespread to the north and east of Gembrook. In the lower areas of the eastern slopes, the ground stratum has greater cover of *Gahnia radula* and Forest Wire Grass *Tetrarrhena juncea* with a medium to tall shrub layer. The taller tree stratum on the south-east slopes is dominated by *E. cypellocarpa* and has a grassy understorey dominated by *Poa labillardierei*. Shrubs are infrequent and are mostly *Cassinia aculeata*. This is the habitat of Purple Eyebright *Euphrasia collina*, a rarely seen plant in the reserve, and is aligned with the Herb-rich Foothill Forest EVC 23.

Riparian Scrub/Swampy Riparian Woodland EVC 17 (Fig. 5)

This EVC is described by Tonkinson (1995) as riparian forest and is equivalent to the Swamp Gum Swampy Riparian Woodland (Community 19) of Brown (2005). It occurs on waterlogged soils or is associated with low energy streams, where it forms a dense shrubland or woodland 10–15 m tall (DELWP 2016). The upper stratum is dominated by *Eucalyptus cypellocarpa and E. ovata*. The ground stratum can be species-poor and dominated by sedges on wetter sites, or by a range of large to medium shrubs in combination with large tussock grasses and sedges. The shrub layer is well developed and moderately diverse, with Hairpin Banksia *Banksia spinulosa*, Snowy

Daisy-bush *Olearia lirata* and Scented Paperbark *Melaleuca squarrosa*.

Biological Significance

At the regional scale (Westernport Catchment), 35 species of vascular plants found at MCFFR are considered significant (Opie *et al.* 1984, Tonkinson 1995): Heath Wattle *Acacia brownii*, Necklace Fern *Asplenium flabellifolium*, Hairpin Banksia *Banksia spinulosa*, Blue Pincushion *Brunonia australis*, Pink Purslane *Calandrinia calyptrata*, Common Everlasting *Chrysocephalum apiculatum*, Common Billy-buttons *Craspedia variabilis*, Small Tongue-orchid *Cryptostylis leptochila*, Austral Bear's-ear *Cymbonotus preissianus*, Pale Flax-lily *Dianella longifolia*, Tiny Sundew *Drosera pygmaea*, Parsons Bands *Eriochilus cucullatus*, Purple Eyebright *Euphrasia collina*, Cinnamon Bells *Gastrodia sesamoides*, Wax-lip Orchid *Glossodia major*, Lanky Goodenia *Goodenia elongata*, Hairy Brooklime *Gratiola pubescens*, Moss Sunray *Hyalosperma demissum*, Hairy Stylewort *Levenhookia dubia*, Tufted Lobelia *Lobelia rhombifolia*, Rough Daisy-bush *Olearia asterotricha*, Austral Adder's-tongue *Ophioglossum lusitanicum*, Long Purple-flag *Patersonia occidentalis*, Yellow Star *Pauridia glabella*, Pygmy Clubmoss *Phylloglossum drummondii*, Australian Buttercup *Ranunculus lappaceus*, Yellow Sebaea *Sebaea ovata*, Prickly Starwort *Stellaria pungens*, Hundreds and Thousands *Stylidium despectum*, Hairy Speedwell *Veronica calycina*, Trailing Speedwell *Veronica plebeia*, Early Nancy *Wurmbea dioica*, Small Grass-tree *Xanthorrhoea minor*, and Hill Xanthosia *Xanthosia tridentata*.

More recent survey work and understanding of the floristics of MCFFR now recognise an additional eight species and two plant communities that are of significance because they are rare, vulnerable or poorly known at a regional or State level: Summer Spider-orchid *Caladenia flavovirens* (State significance), Wine-lipped Spider-orchid *Caladenia oenochila* (State significance), Fringed Helmet-orchid *Corybas fimbriatus*, Green-striped Greenhood *Pterostylis chlorogramma* (National and State significance), Cobra Greenhood *Pterostylis grandiflora*, Red-tipped Greenhood *Pterostylis sp.* aff. *parviflora* (Southern Victoria), Forest Sun-orchid *Thelymitra arenaria*.

The Riparian Scrub/Swampy Riparian Woodland EVC is considered vulnerable and the Damp Heathy Woodland EVC 793 is considered depleted (DELWP 2016). Heathy Woodland dominated by *E. cephalocarpa* is extremely depleted due to clearing from quarrying, urban expansion and agriculture, and is considered of regional significance. While both these EVCs occur in other bioregions within the State, their status in the Highlands–Southern Fall bioregion is tenuous. The Blackthorn Scrub EVC 27 is rare in the Highlands Southern Fall bioregion.

Amos (2004) provides standard criteria for determining sites of significance in Victoria. A set of five broad criteria, which are divided into sub-criteria, facilitate identification of significance at four possible levels: National, State, Regional (Bioregional) or local. The significance level of a site is equal to that of the single highest rating for any particular asset. We consider MCFFR to be of State significance based on its richness and diversity (Criterion 2.1), primarily because of the exceptionally rich orchid flora, as well as the rarity and conservation status of its assets (Criteria 3.1, 3.1.2, 3.2, 3.2.3). At MCFFR, nine vascular plant species are listed within the Advisory List of Rare or Threatened Plants in Victoria (DEPI 2014), and one EVC is listed as vulnerable in the bioregion while another is listed as depleted. The reserve is identified with very high to high conservation rating in Nature Print: Strategic Natural Values (DELWP 2017).

Species of interest

Eucalyptus fulgens

A Victorian endemic species found in low numbers on the plateau, upper western slopes and rocky outcrops of Mt Cannibal. It was first collected at MCFFR by JC Reid in 1994 and occurs east from Healesville and Woori Yallock to the Latrobe Valley, near Driffield. Considered near threatened to rare. Present in nearby areas at Bunyip and Pakenham.

Euphrasia collina

Recorded from the south-east slopes of Mt Cannibal (Tonkinson 1995). Although the subspecies is not known, it is very likely to be *E. collina* subsp. *collina*, which is scattered

across southern Victoria in sclerophyll forest and woodland. It is less likely to be *E. collina* subsp. *muelleri* which is endangered and now restricted to the Mornington Peninsula. Further effort is needed to clarify the identification of this record.

Pterostylis chlorogramma
Recorded from two locations on the western slopes of Mt Cannibal. A poorly known member of the *P. longifolia* complex and appears to be more common than once thought (G. Backhouse pers. comm. 2016). *Pterostylis chlorogramma* is readily confused with Emerald-lip Greenhood *P. smaragdyna* which has larger flowers with stronger colour. The closely related and more common *P. melagramma* is also present in MCFFR, but is uncommon. Further searches, particularly in the more inaccessible areas of the reserve, may reveal a broader distribution of members of the *P. longifolia* complex.

Caladenia oenochila
Caladenia oenochila is recorded from three locations, where it is vulnerable to disturbance. It has also been recorded from the nearby Cannibal Creek Reserve (Tonkinson *et al.* 2003) and is endemic to Victoria where it is vulnerable and confined to the Highland–Southern Fall bioregion, apart from an isolated record from Anglesea. Populations are patchy and uncommon throughout its range (G Backhouse pers. comm. 2016). Flowering can be enhanced by summer fires (Royal Botanic Gardens 2017). *Caladenia oenochila* forms hybrids with Mantis Orchid *C. tentaculata* and *C. flavovirens* in the region (Jeanes and Backhouse 2006).

Caladenia flavovirens
A widespread species and scattered across southern Victoria where it occurs in heathy woodlands and moist foothill forests. Rare and seldom seen, usually flowering only after fire (Jeanes and Backhouse 2006). Often difficult to distinguish from Mountain Summer Spider-orchid *C. aestiva*. Recorded at two sites at Mt Cannibal in moist lowland forest on the south-western slopes.

Olearia asterotricha* subsp. *lobata
Rare in Victoria where it occurs in moist forest and swampy heathland in a few disjunct areas of southern Victoria. In 1995 the species was uncommon at MCFFR, where it was restricted to the eastern boundary. Populations outside the reserve were vulnerable to disturbance and loss associated with roadside management. In 2016, no plants could be found in the reserve or the adjacent road reserve.

Eucalyptus globoidea
Eucalyptus globoidea occurs over much of MCFFR and is a dominant canopy tree in the lowland forest, particularly on the western and northern slopes. Its occurrence at MCFFR is near the western limit of the species and the community it forms is uncommon to rare within the region. The species is more common and widespread in eastern Victoria.

Management issues
Fire
The Department of Environment, Land, Water and Planning and local Country Fire Authority (CFA) brigades have no records or memory of bushfires at Mt Cannibal within the last 40 years. A lightning strike occurred on 14 February 2014, setting a tree alight, but the fire did not spread further as it was quickly extinguished by the CFA (G Burns pers. comm. 2016). A small fire had occurred to the south of the northern lookout less than five years prior to the assessment by Tonkinson in 1995; this may also have been from a lightning strike and extended no more than 20 square metres. Fire scars (charcoal bark) are evident on trees elsewhere within the reserve, particularly on the northern and eastern slopes, but the age of these scars and extent of burning is undetermined. It is surprising that wildfire has been infrequent in this reserve as the overall fuel hazard rating, using the western slopes as a guide, is Extreme (Hines *et al.* 2010).

The long absence of fire at MCFFR undoubtedly has been an important influence on the floristics and structure of the vegetation, as many species in the reserve are reliant on fire for regeneration. The current absence of *Goodia lotifolia*, a species recorded by Opie *et al.* in 1984 (Opie 1984) is likely a result of long fire intervals. In the *E. cephalocarpa* dominated lowland forest of the western slopes, Furze Hakea *Hakea ulicina* is in severe decline due to

senescence from the absence of fire (Tonkinson 1995). In 2016, only three plants were located in the reserve, all on the lower western slopes. The continued absence of fire could result in a decline in the above-ground richness or abundance of fire-promoted species, particularly in the families Orchidaceae, Fabaceae, Geraniaceae, Proteaceae, Liliaceae, and Asteraceae. However, most species are expected to persist in the soil-seed bank, and their conservation status requires reassessment in the next post-fire period.

The establishment and spread of Sweet Pittosporum *Pittosporum undulatum* over large sections of the reserve has been facilitated by the long inter-fire period at MCFFR. *Pittosporum undulatum* is readily killed by fire. In contrast, the invasive and problematic Berry-flowered Heath *Erica baccans* and Spanish Heath *E. lusitanica* are promoted by fire, and the long absence of fire at MCFFR may have slowed their spread. Despite this, *E. baccans* has become well established at MCFFR and forms dense thickets on the higher slopes of Mt Cannibal.

The implementation of a prescribed ecologically-based fire management plan is required for MCFFR to ensure that its biological richness and abundance is not further compromised. However, due to the reserve's botanical and zoological values, the comparative isolation of its vegetation in the immediate landscape, as well as its steepness and restricted access, small scale 'patch' burns are likely to work best.

Exotic species

Exotic plants significantly threaten the preservation and enhancement of biodiversity values by outcompeting and replacing native species. Of the 58 invasive species recorded in 1995 (Tonkinson 1995), five are problematic and require attention: Sweet Pittosporum *Pittosporum undulatum*, *Erica baccans*, Spanish Heath *E. lusitanica*, European Blackberry *Rubus anglocandicans*, and Ragwort *Senecio jacobaea*.

Berry-flowered Heath is highly damaging to the ecology and diversity of Mount Cannibal as it forms dense thickets to 2 m high. It was first recorded as naturalised in Victoria at Tynong in 1914, when it was collected by E Cheel, with the note 'probably an escape'. More recently, the species was grown as a cut-flower in the vicinity of Mount Cannibal (Opie *et al.* 1984). Invasions of Berry-flowered Heath have been an ongoing issue at Mount Cannibal. Current infestations occur over large areas of the northern, western and southern slopes, and require management intervention. A large-scale suppression program was initiated in 2015, using teams of contractors and volunteers using manual removal, cut and paint methods, and brush-cutting. Cutting large plants near ground level without application of herbicide appears to be fatal to many plants. Continued effort over 5 to 10 years, followed by regular surveillance and control as necessary, will be required to prevent further spread of this species. Infestations of *E. baccans* also are likely to have an impact on the hydrology of rock outcrop vegetation, by causing intense competition for water, possibly shortening the growing season for many indigenous species and leading to fewer and smaller individuals. The fire response of *E. baccans* is not reliably documented. There are indications that plants are killed by fire but regenerate from soil-seed banks, and that their seed is short-lived (Spooner 1999; Holmes and Newton 2004; S Harris pers. obs. 2016). Clarification in Australian environments is needed to inform fire management planning in the MCFFR.

Although infestations of *E. lusitanica* are presently small at MCFFR, the species is an aggressive invader in the region and capable of causing catastrophic impacts on biodiversity values. Similarly, infestations of the high risk weeds—*Rubus anglocandicans*, Agapanthus *Agapanthus praecox*, Cotoneaster *Cotoneaster* spp., Sallow Wattle *Acacia longifolia*, White Sallow Wattle *A. floribunda*, Red Cestrum *Cestrum elegans* and Bulbil Watsonia *Watsonia meriana*—are restricted at Mount Cannibal, but have the potential to expand (Adair 2015; pers. obs. 2016).

An active and long-running weed control program involving both the community (Friends of Mt Cannibal Inc.) and Cardinia Shire Council has helped arrest the invasion and spread of a range of high risk environmental weeds. More recent weed control has been extended, involving neighbours to the reserve and local Landcare groups through continued funding from Council's weed grant program for private property owners, Catchment Management Authority (CMA) and Melbourne Water

funding targeting roadsides, streamsides and other land.

A commitment to a long-term weed control program from Council, CMA and the community is necessary for both public and private land to add to and maintain the gains achieved to date, and to ensure the protection of the high biodiversity values of Mount Cannibal.

Track management

A 2.2 kilometre circuit walking track is popular with visitors at MCFFR. The circuit passes through the northern and southern lookout areas, which provide spectacular views of the surrounding landscapes. Unfortunately, pedestrian traffic is causing soil compaction, leading to soil erosion especially on shallow soils, particularly in the vicinity of the northern and southern lookouts, where the impact on shallow-soil ephemerals and geophytes is considerable. Steep sections of the walking trail below the outcrops suffer from erosion, shifting soil into surrounding vegetation or onto flatter areas of the trail. The construction of raised platforms and boardwalks in erosion-prone areas would reduce visitor impacts in these areas considerably and help protect a number of regionally significant plants that are largely restricted to these habitats.

Vertebrate Pests

Rabbit grazing is apparent in the vegetation of the northern and southern outlooks and boulder sheets across the plateau area. It seems less severe elsewhere in the reserve. Rabbit grazing may contribute to the 'lawn-like' appearance of the summit and outlook vegetation, and is likely to have a severe effect on the survival prospects of species restricted to this habitat. Baiting programs across all land tenures are required, preferably at a catchment level, to reduce the impacts of rabbits at MCFFR. A local, highly successful fox control shooting program around the reserve could be extended to include rabbits.

Heavy grazing, resting and trampling impacts from the Eastern Grey Kangaroo are evident on the eastern slopes of Mt Cannibal. The reserve clearly provides day-time shelter for mobs that graze local pastures. Their impact on indigenous flora in MCFFR has not been documented, but appears to be considerable.

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Table 1. Census of higher plants recorded for Mt Cannibal Flora and Fauna Reserve, Garfield North, Victoria
#= regionally significant, v =vulnerable in Victoria, r= rare in Victoria, Vu=vulnerable nationally

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Adiantaceae						
Adiantum aethiopicum	Common Maidenhair		*	*	*	
Cheilanthes austrotenuifolia	Green Rock Fern		*		*	
Aspleniaceae						
Asplenium flabellifolium	Necklace Fern	#	*		*	
Dennstaedtiaceae						
Calochlaena dubia	Common Ground Fern		*		*	
Pteridium esculentum	Austral Bracken		*	*	*	
Lindsaeaceae						
Lindsaea linearis	Screw Fern		*	*	*	
Polypodiaceae						
Microsorum pustulatum	Kangaroo Fern		*			
Lycopodiaceae						
Phylloglossum drummondii	Pygmy Clubmoss	#	*			
Ophioglossaceae						
Ophioglossum lusitanicum	Austral Adder's-tongue	#	*		*	
Selaginellaceae						
Selaginella uliginosa	Swamp Selaginella		*			
Pinaceae						
* *Pinus radiata*	Monterey Pine		*		*	
Amaryllidaceae						
* *Agapanthus praecox*	Agapanthus				*	
* *Allium triquetrum*	Angled Onion				*	
Asparagaceae						
Arthropodium strictum	Chocolate Lily		*		*	
Thysanotus patersonii	Twining Fringe-lily		*			
Thysanotus tuberosus	Common Fringe-lily		*		*	
Colchicaceae						
Burchardia umbellata	Milkmaids		*		*	
Wurmbea dioica	Early Nancy	#	*		*	
Asphodelaceae						
Caesia parviflora	Pale Grass-lily		*		*	
Chamaescilla corymbosa	Blue Stars		*			
Dianella admixta	Black-anthered Flax-lily		*		*	
Dianella longifolia	Pale Flax-lily	#	*			
Tricoryne elatior	Yellow Rush-lily		*		*	
Centrolepidaceae						
Aphelia pumilio	Dwarf Aphelia		*			
Centrolepis aristata	Pointed Centrolepis		*			
Centrolepis strigosa	Hairy Centrolepis		*		*	
Cyperaceae						
Carex breviculmis	Grassland Sedge		*		*	
* *Cyperus eragrostis*	Drain Flat-sedge		*			
* *Isolepis levynsiana*	Tiny Flat-sedge		*		*	
Eleocharis sphacelata	Tall Spike-sedge		*		*	
Gahnia radula	Thatch Saw-sedge		*	*	*	
Isolepis marginata	Club-sedge				*	

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Lepidosperma laterale	Variable Sword-sedge		*	*	*	
Schoenus apogon	Common Bog-rush		*		*	
Iridaceae						
* *Romulea rosea*	Common Onion-grass		*			
* *Sisyrinchium iridifolium*	Scour Weed		*		*	
* *Watsonia meriana*	Bulbil Watsonia		*		*	
Patersonia occidentalis	Long Purple-flag	#		*		
Junaceae						
Juncus ?holoschoenus	Joint-leaf Rush		*			
* *Juncus articulatus*	Jointed Rush				*	
Juncus bufonius	Toad Rush		*			
* *Juncus capitatus*	Capitate Rush		*			
Juncus planifolius	Broad-leaf Rush				*	
Juncus procerus	Tall Rush		*			
Juncus subsecundus	Finger Rush		*			
Luzula meridionalis var. *densiflora*	Woodrush		*			
Luzula meridionalis var. *flaccida*	Woodrush		*		*	
Hypoxidaceae						
Hypoxis hydrometrica var. *hydrometrica*	Golden Weather-glass		*		*	
Pauridia glabella	Yellow Star	#		*		
Orchidaceae						
Acianthus caudatus	Mayfly Orchid					*
Acianthus exertus	Large Mosquito Orchid				*	*
Acianthus pusillus	Small Gnat Orchid		*			*
Caladenia praecox	Early Caladenia					*
Caladenia? dilatata	Green-comb Spider-orchid				*	
Caladenia carnea	Pink Fingers		*			*
Caladenia catenata	White Fingers	#			*	*
Caladenia flavovirens	Summer Spider-orchid	r				*
Caladenia moschata	Musky Caldenia		*			*
Caladenia oenochila	Wine-lipped Spider-orchid	v				*
Caladenia parva	Small Spider-orchid					*
Caladenia pusilla	Tiny Fingers					*
Caladenia tentaculata	Mantis Orchid					*
Caladenia transitoria	Eastern Bronze-orchid					*
Calochilus campestris	Copper Beard-orchid					*
Calochilus robertsonii	Purple Beard-orchid				*	
Chiloglottis valida	Common Bird-orchid		*		*	*
Corunastylis despectans	Sharp Midge-orchid				*	
Corybas diemenicus	Veined Helmet-orchid				*	
Corybas fimbriatus	Fringed Helmet-orchid	#, r				*
Corybas incurvus	Slaty Helmet-orchid				*	
Cryptostylis leptochila	Small Tongue-orchid	#	*			*
Cryptostylis subulata	Large Tongue-orchid				*	
Cyrtostylis reniformis	Small Gnat-orchid				*	
* *Dendrobium kingianum*	Pink Rock Orchid			*		
Dipodium roseum	Hyacinth Orchid		*		*	*
Diuris orientis	Wallflower Orchid				*	
Diuris pardina	Leopard Orchid		*			*
Diuris sulphurea	Tiger Orchid		*		*	*
Eriochilus cucullatus	Parsons Bands	#	*			*
Gastrodia procera	Tall Potato-orchid				*	

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Gastrodia sesamoides	Cinnamon Bells	#	*			*
Glossodia major	Wax-lip Orchid	#	*			*
Leptoceras menziesii	Hare Orchid					*
Microtis arenaria	Notched Onion-orchid					*
Microtis parviflora	Slender Onion-orchid		*			*
Microtis rara	Scented Onion-orchid					*
Microtis unifolia	Common Onion-orchid		*			*
Orthoceras strictum	Horned Orchid					*
Pterostylis alpina	Mountain Greenhood		*		*	*
Pterostylis atrans	Dark-tip Greenhood					*
Pterostylis chlorogramma	Green-striped Greenhood	Vu, v				*
Pterostylis sp. aff. *parviflora*	Red-tipped Greenhood	#, r				*
Pterostylis foliata	Slender Greenhood					*
Pterostylis grandiflora	Cobra Greenhood	#, r				*
Pterostylis melagramma	Tall Greenhood		*			*
Pterostylis parviflora	Tiny Greenhood					*
Pterostylis sp. aff. *melagramma*	Dainty Greenhood					*
Pterosylis nutans	Nodding Greenhood					*
Pyrorchis nigricans	Red-beaks					*
Thelymitra arenaria	Forest Sun-orchid	#				*
Thelymitra aristata	Great Sun-orchid		*			
Thelymitra ixioides	Spotted Sun-orchid					*
Thelymitra juncifolia	Rush-leaf Sun-orchid					*
Thelymitra media	Tall Sun-orchid					*
Thelymitra pauciflora	Slender Sun-orchid		*			*
Thelymitra rubra	Salmon Sun-orchid					*
Poaceae						
**Agrostis capillaris*	Brown-top Bent		*			
**Agrostis stolonifera*	Creeping Bent		*			
**Aira caryophyllea*	Silvery Hair-grass		*			
**Aira cupaniana*	Hair-grass				*	
**Aira elegantissima*	Hair-grass				*	
**Aira praecox*	Hair-grass				*	
**Anthoxanthum odoratum*	Sweet Vernal-grass		*		*	
Austrostipa muelleri	Wiry Spear-grass		*		*	
Austrostipa pubinodis	Tall Spear-grass		*			
Austrostipa rudis subsp. *australis*	Veined Spear-grass	r	*			
**Briza maxima*	Large Quaking Grass		*		*	
**Briza minor*	Lesser Quaking Grass		*		*	
**Bromus hordeaceus*	Soft Brome		*			
**Cynodon dactylon*	Couch		*			
**Dactylis glomerata*	Cocksfoot				*	
Dichelachne micrantha	Short-hair Plume-grass		*			
Echinopogon ovatus	Common Hedgehog-grass		*			
Eragrostis brownii	Common Love-grass		*			
**Ehrharta erecta*	Panic Veldt-grass				*	
Hemarthria uncinata	Mat Grass		*			
**Holcus lanatus*	Yorkshire Fog		*			
Imperata cylindrica	Blady Grass		*	*	*	
Lachnagrostis aemula	Leafy Blown-grass		*			
**Lolium perenne*	Perennial Rye-grass		*		*	
Microlaena stipoides	Weeping Grass		*	*	*	
**Paspalum dilatatum*	Paspalum		*			
**Paspalum distichum*	Water Couch		*			

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Pentapogon quadrifidus	Five-awned Spear-grass		*			
*Poa annua	Annual Meadow-grass		*		*	
Poa labillardierei	Common Tussock-grass		*		*	
Poa morrisii	Soft Tussock-grass		*			
*Poa pratensis	Smooth Meadow-grass					
Poa sieberiana	Grey Tussock-grass		*		*	
Poa tenera	Slender Tussock-grass		*		*	
Rytidosperma geniculatum	Kneed Wallaby-grass		*			
Rytidosperma penicillatum	Slender Wallaby-grass		*			
Rytidosperma pilosum	Velvet Wallaby-grass		*	*		
Rytidosperma racemosum	Wallaby-grass		*			
Rytidosperma semiannulare	Heath Wallaby-grass		*			
Rytidosperma setaceum	Bristly Wallaby-grass		*			
Rytidosperma caespitosum	Common Wallaby-grass		*			
Rytidosperma pallidum	Silvertop Wallaby-grass		*		*	
*Setaria verticillata	Whorled Pigeon-grass		*			
*Sporobolus africanus	Rat's-tail Grass		*			
Tetrarrhena juncea	Forest Wire-grass		*	*	*	
Themeda triandra	Kangaroo Grass		*		*	
*Vulpia bromoides	Squirrel-tail Fescue		*		*	
Restionaceae						
Empodisma minus	Spreading Rope-rush		*	*	*	
Lepyrodia muelleri	Common Scale-rush		*		*	
Xanthorhoeaceae						
Lomandra filiformis subsp. coriacea	Wattle Mat-lily				*	
Lomandra filiformis subsp. filiformis	Wattle Mat-lily		*	*	*	
Lomandra longifolia subsp. exilis	Spiny-headed Mat-lily				*	
Lomandra longifolia subsp. longifolia	Spiny-headed Mat-lily		*	*	*	
Xanthorrhoea minor subsp. lutea	Small Grass-tree	#	*		*	
Apiaceae						
Centella cordifolia	Centella		*		*	
Platysace heterophylla	Heathy Platysace		*		*	
Xanthosia dissecta	Cut-leaf Xanthosia		*			
Xanthosia tridentata	Hill Xanthosia	#	*			
Apocynaceae						
Parsonsia brownii	Twining Silkpod		*			
Araliaceae						
* Hedera helix	English Ivy		*		*	
Hydrocotyle callicarpa	Small Pennywort		*		*	
Hydrocotyle foveolata	Yellow Pennywort		*		*	
Hydrocotyle hirta	Hairy Pennywort		*	*		
Polyscias sambucifolius subsp. 3	Elderberry Panax		*	*	*	
Asteraceae						
*Arctotheca calendula	Cape Weed		*			
*Bellis perennis	English Daisy				*	
Cassinia aculeata	Common Cassinia		*	*	*	
Cassinia longifolia	Shiny Cassinia		*		*	
Chrysocephalum apiculatum	Common Everlasting	#	*			

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Chrysocephalum semipapposum	Clustered Everlasting		*			
**Cirsium vulgare*	Spear Thistle		*		*	
Coronidium scorpioides	Button Everlasting		*	*	*	
Craspedia variabilis	Common Billy-buttons	#	*		*	
Cymbonotus preissianus	Austral Bear's-ears	#	*		*	
**Erigeron* sp.	Fleabane		*			
Euchiton involucratus	Cudweed		*			
Euchiton japonicus	Creeping Cudweed				*	
Euchiton sphaericus	Common Cudweed		*			
**Gamochaeta calviceps*	Cudweed		*			
**Gamochaeta purpurea*	Purple Cudweed		*			
Hyalosperma demissum	Moss Sunray	#	*			
**Hypochoeris radicata*	Cat's Ear		*	*	*	
Lagenophora gracilis	Slender Lagenophora		*		*	
Lagenophora stipitata	Common Lagenophora		*	*		
**Leontodon saxatilis* subsp. *saxatilis*	Hairy Hawkbit		*		*	
Olearia asterotricha subsp. *lobata*	Rough Daisy-bush	#, r	*			
Olearia lirata	Snowy Daisy-bush		*		*	
Olearia phlogopappa subsp. *continentalis*	Dusty Daisy-bush				*	
Olearia ramulosa var. *ramulosa*	Twiggy Daisy-bush		*		*	
Ozothamnus ferrugineus	Tree Everlasting		*	*	*	
**Picris hieracioides*	Hawkweed Picris		*			
Senecio glomeratus	Annual Fireweed		*		*	
Senecio hispidulus	Rough Fireweed		*			
Senecio minimus	Shrubby Fireweed				*	
Senecio prenanthoides	Beaked Fireweed				*	
Senecio quadridentatus	Cottony Fireweed			*	*	
**Senecio jacobea*	Ragwort		*		*	
Sigesbeckia orientalis	Indian Weed		*		*	
Solenogyne dominii	Solengyne		*			
**Sonchus oleraceus*	Sow Thistle		*		*	
Bignoniaceae						
Pandorea pandorana	Wonga Vine		*		*	
Boraginaceae						
Cynoglossum suaveolens	Sweet Hound's-tongue		*		*	
Brassicaceae						
**Cardamine occulta*	Bitter-cress				*	
Campanulaceae						
Lobelia anceps	Angled Lobelia				*	
Lobelia rhombifolia	Tufted Lobelia	#	*			
Wahlenbergia gracilenta	Annual Bluebell		*		*	
Wahlenbergia gracilis	Sprawling Bluebell		*			
Wahlenbergia stricta	Tall Bluebell		*		*	
Caryophyllaceae						
**Cerastium glomeratum*	Common Mouse-ear Chickweed		*		*	
**Polycarpon tetraphyllum*	Four-leaved Allseed				*	
Stellaria pungens	Prickly Starwort	#	*		*	

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Casuarinaceae						
Allocasuarina paludosa	Scrub Sheoak		*		*	
Celastraceae						
Stackhousia monogyna	Creamy Candles		*			
Clusiaceae						
Hypericum gramineum	Small St John's Wort		*	*	*	
Convolvulaceae						
Dichondra repens	Kidney-weed		*	*	*	
Crassulaceae						
Crassula helmsii	Swamp Crassula		*			
Crassula sieberiana	Sieber Crassula		*		*	
Cunoniaceae						
Bauera rubioides	Wiry Bauera		*	*	*	
Droseraceae						
Drosera aberrans	Scented Sundew		*		*	
Drosera auriculata	Tall Sundew		*	*	*	
Drosera hookeri	Pale Sundew		*	*		
Drosera pygmaea	Tiny Sundew	#	*			
Elaeocarpaceae						
Tetratheca ciliata	Pink Bells				*	
Ericaceae						
Acrotriche prostrata	Trailing Ground-berry		*	*	*	
Acrotriche serrulata	Honey-pots		*		*	
Astroloma humifusum	Cranberry Heath		*		*	
Epacris impressa	Common Heath		*	*	*	
**Erica baccans*	Berry-flowered Heath		*		*	
**Erica lusitanica*	Spanish Heath		*		*	
Euphorbiaceae						
Amperea xiphoclada	Broom Spurge		*	*		
Fabaceae						
Acacia brownii	Heath Wattle	#	*			
Acacia dealbata	Silver Wattle		*		*	
**Acacia decurrens*	Early Black Wattle		*			
**Acacia floribunda*	White Sallow Wattle				*	
Acacia genistifolia	Spreading Wattle		*		*	
**Acacia longifolia*	Sallow Wattle				*	
Acacia mearnsii	Black Wattle		*		*	
Acacia melanoxylon	Blackwood		*		*	
Acacia mucronata	Narrow-leaf Wattle		*		*	
Acacia myrtifolia	Myrtle Wattle				*	
Acacia stricta	Hop Wattle		*	*	*	
Acacia verticillata subsp. *verticillata*	Prickly Moses		*		*	
Bossiaea prostrata	Creeping Bossiaea		*		*	
Daviesia latifolia	Hop Bitter-pea		*		*	
Desmodium gunnii	Slender Tick-trefoil		*		*	
Dillwynia cinerascens	Grey Parrot-pea		*			
Dillwynia glaberrima	Smooth Parrot-pea		*			
Glycine clandestina	Twining Glycine		*	*	*	

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Goodia lotifolia	Golden Tip			*		
Hardenbergia violacea	Purple Coral-pea		*		*	
Hovea heterophylla	Common Hovea		*		*	
Indigofera australis	Austral Indigo		*		*	
Kennedia prostrata	Running Postman		*			
**Lotus subbiflorus*	Hairy Bird's-foot Trefoil		*			
**Medicago* sp.	Medic				*	
**Ornithopus pinnatus*	Sand Bird's-foot		*			
Platylobium obtusangulum	Common Flat-pea		*			
Platylobium ?reflexum	Flat-pea		*			
Pultenaea gunnii	Golden Bush-pea		*	*		
Pultenaea hispidula	Rusty Bush-pea		*		*	
Pultenaea scabra	Rough Bush-pea			*		
**Trifolium dubium*	Suckling Clover		*		*	
**Trifolium repens*	White Clover		*			
**Vicia sativa*	Common Vetch		*			
Gentianaceae						
Sebaea ovata	Yellow Sebaea	#	*			
**Centaurium erythraea*	Common Centaury		*		*	
**Centaurium pulchellum*	Lesser Centaury			*		
**Centaurium tenuiflorum*	Slender Centaury		*			
**Cicendia filiformis*	Slender Cicendia		*		*	
Geraniaceae						
Geranium ?homeanum	Crane's-bill		*			
Geranium solanderi 'soft'	Crane's-bill		*	*		
Pelargonium ?inodorum	Kopata				*	
Pelargonium australe	Austral Stork's-bill		*			
Pelargonium rodneyanum	Magenta Stork's-bill			*	*	
Goodeniaceae						
Brunonia australis	Blue Pincushion	#	*		*	
Goodenia elongata	Lanky Goodenia	#	*		*	
Goodenia humilis	Swamp Goodenia		*			
Goodenia lanata	Trailing Goodenia		*	*	*	
Goodenia ovata	Hop Goodenia		*		*	
Haloragaceae						
Gonocarpus humilis	Shade Raspwort				*	
Gonocarpus micranthus	Creeping Raspwort		*			
Gonocarpus tetragynus	Common Raspwort		*	*	*	
Lamiaceae						
**Lamium amplexicaule*	Dead Nettle				*	
Prunella vulgaris	Self-heal		*			
Lauraceae						
Cassytha melantha	Coarse Dodder-laurel				*	
Loranthaceae						
Amyema pendulum	Drooping Mistletoe		*		*	
Lythraceae						
Lythrum hyssopifolium	Small Loosestrife		*			
**Lythrum junceum*	Mediterranean Loosestrife				*	
Myrtaceae						
Eucalyptus baxteri	Brown Stringybark		*			
**Eucalyptus botryoides*	Southern Mahogany				*	
Eucalyptus cephalocarpa	Silver-leaf Stringybark		*		*	
Eucalyptus cypellocarpa	Mountain Grey Gum		*	*	*	

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Eucalyptus dives	Broad-leaf Peppermint		*		*	
Eucalyptus fulgens	Green Scent-bark	r				
Eucalyptus globoidea	White Stringybark		*	*	*	
Eucalyptus obliqua	Messmate		*	*	*	
Eucalyptus ovata	Swamp Gum		*		*	
Eucalyptus radiata	Narrow-leaf Peppermint		*	*	*	
Eucalyptus viminalis subsp. *viminalis*	Manna Gum				*	
Kunzea ericoides sens.lat.	Burgan		*		*	
Leptospermum continentale	Prickly Tea-tree		*	*	*	
Leptospermum myrsinoides	Heath Tea-tree		*			
Melaleuca ericifolia	Swamp Paperbark		*		*	
Melaleuca squarrosa	Scented Paperbark		*		*	
Orobanchaceae						
Euphrasia collina	Purple Eyebright		*			
Oxalidaceae						
Oxalis exilis	Shady Wood-sorrel		*		*	
**Oxalis incarnata*	Pale Wood-sorrel				*	
**Oxalis pes-caprae*	Soursob				*	
Oxalis perennans	Wood-sorrel				*	
Phyllanthaceae						
Poranthera microphylla	Small Poranthera		*		*	
Phytolaccaceae						
**Phytolacca octandra*	Inkweed				*	
Pittosporaceae						
Billardiera mutabilis	Common Apple-berry		*	*	*	
Bursaria spinosa	Sweet Bursaria		*	*	*	
**Pittosporum undulatum*	Sweet Pittosporum		*		*	
Plantaginaceae						
Gratiola pubescens	Hairy Brooklime		*			
**Plantago coronopus*	Buck's-horn Plantain		*			
Plantago debilis	Shade Plantain		*		*	
* *Plantago lanceolata*	Ribwort		*		*	
Veronica calycina	Hairy Speedwell		*			
Veronica derwentiana	Derwent Speedwell		*			
Veronica plebia	Trailing Speedwell		*		*	
Polygalaceae						
Comesperma volubile	Love Creeper		*		*	
Polygonaceae						
**Acetosella vulgaris*	Sheep Sorrel		*			
**Rumex conglomeratus*	Clustered Dock		*			
Portulaceae						
Calandrinia calyptrata	Pink Purslane	#	*		*	
Primulaceae						
**Lysimachia arvensis*	Pimpernel		*		*	
Proteaceae						
Banksia marginata	Silver Banksia		*		*	
Banksia spinulosa	Hairpin Banksia	#	*	*	*	
Hakea nodosa	Yellow Hakea		*		*	
Hakea ulicina	Furze Hakea		*		*	

Table 1. Cont.

Species	Common Name	Significance	Tonkinson (1995)	Opie (1984)	Adair (2015–16)	Piko (2008–13)
Isopogon ceratophyllus	Horny Cone-bush		*		*	
Lomatia ilicifolia	Holly Lomatia		*		*	
Persoonia juniperina	Prickly Geebung		*			
Ranunculaceae						
Clematis aristata	Mountain Clematis		*		*	
Ranunculus lappaceus	Australian Buttercup	#	*		*	
Rhamnaceae						
Spyridium parvifolium	Australian Dusty Miller		*		*	
Rosaceae						
Acaena novae-zelandiae	Bidgee-widgee		*		*	
Acaena sp.	Sheep's Burr		*			
**Aphanes arvensis*	Parsley Piert				*	
**Cotoneaster ?glaucophyllus*	Cotoneaster				*	
**Malus pumila*	Domestic Apple		*			
**Prunus cerasifera*	Cherry Plum		*			
**Rubus anglocandicans*	Blackberry		*		*	
Rubus parvifolius	Small-leaf Bramble		*		*	
**Rosa rubiginosa*	Sweet Briar		*			
Rubiaceae						
Asperula conferta	Common Woodruff		?*		*	
**Galium aparine*	Cleavers				*	
Galium binifolium subsp. *conforme*	Reflexed Bedstraw				*	
Galium leiocarpum	Maori Bedstraw		*	*	*	
Opercularia varia	Variable Stinkweed		*			
Santalaceae						
Exocarpos cupressiformis	Cherry Ballart		*		*	
Exocarpos strictus	Pale-fruit Ballart		*		*	
Solanaceae						
**Cestrum elegans*	Red Cestrum				*	
**Solanum nigrum*	Black Nightshade		*		*	
Stylidiaceae						
Levenhookia dubia	Hairy Stylewort	#	*			
Stylidium despectum	Hundreds and Thousands	#	*			
Stylidium graminifolium	Grass Trigger-plant		*		*	
Thymelaeaceae						
Pimelea humilis	Common Rice-flower		*		*	
Violaceae						
Viola hederacea	Ivy-leaf Violet		*	*	*	

Identification of individual Striped Legless Lizards *Delma impar* using the dorsal head scale pattern

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Abstract
Basic aspects of the life history of the Striped Legless Lizard *Delma impar* are poorly understood due to its cryptic habit, poor recapture success and the difficulty in identifying individual animals. Traditional methods used for tagging or marking reptiles have been unsuccessful for the Striped Legless Lizard. The study of unique patterns is increasingly used for the individual identification of a wide range of animal taxa, and a similar approach in the study of the shape and arrangement of scales (lepidosis) has been used for a small number of reptiles. This study assessed whether lepidosis is a viable option for the identification of individual Striped Legless Lizards. It was found that the dorsal head scale pattern was unique to individual animals, that this pattern did not alter with ontogenetic development or over time, and that trained volunteers could achieve a reasonable level of accuracy in distinguishing one individual from another. (*The Victorian Naturalist* **134** (6), 177–186)

Keywords: Individual recognition, lepidosis, individual identification, marking reptiles

Introduction

The ability to identify individual animals provides wildlife managers with the capacity to glean information about the status of populations of interest and the individuals within those populations (Jolly 1965; Seber 1965; Lebreton *et al.* 1992; Pradel 1996). Acquisition of mark-recapture data can lead to a greater understanding of a species' life history, habitat utilisation, and other ecological interactions. Understanding the dynamics of the target population (e.g. abundance, survivorship, growth) is useful for informing wildlife management strategies.

Individual identification may be achieved by the application of a mark or tag or the documentation of uniquely identifying features that distinguish one individual from another (Taber 1956; Woodbury 1956; Hagler and Jackson 2001; Gosler 2004; Plummer and Ferner 2012; Silvy *et al.* 2012). The method of individual identification should be humane, simple, accurate, durable and inexpensive (Murray and Fuller 2000; Southwood and Henderson 2000; Powell and Proulx 2003; McCarthy and Parris 2008). If marks or tags are applied to an animal, they should be physiologically inert and not interfere with behaviour, growth, survival, or probability of recapture (Murray and Fuller 2000; Plummer and Ferner 2012).

Methods for identifying individuals have been developed for all classes of vertebrates, and selection is dependent on aspects such as the form, physiology and habit of the target organism. For reptiles, a range of methods has been developed (Plummer and Ferner 2012). Some examples include:

- Scale clipping (Blanchard and Finster 1933; Brown and Parker 1976; Spellerberg 1977; Fitch 1987; Brown *et al.* 2007);
- Toe clipping (Woodbury 1956; Tinkle 1967; Medica *et al.* 1971; Paulissen and Meyer 2000; Borges-Landáez and Shine 2003; Irschick 2005; Radder *et al.* 2006);
- Pyrobranding (Clark 1971; Ehmann 2000; Winne *et al.* 2006; Vervust and Van Damme 2009; Ekner *et al.* 2011; Hitchmough *et al.* 2012);
- Freeze-branding (Lewke and Stroud 1974; Burns and Heatwole 2000);
- External tags (Rodda *et al.* 1988; Fisher and Muth 1989);
- Passive Integrated Transponders (PIT tags) (Kuhnz 1999; Henke 2008; Le Galliard *et al.* 2011);
- The application of paint, tattoos and Visible Implantable Elastomer (VIE) (Rodda *et al.* 1988; Penney *et al.* 2001; Quinn *et al.* 2001; Hutchens *et al.* 2008; Petit *et al.* 2012); and

- Integument pattern and scale characteristic mapping (Carlström and Edelstam 1946; Rodda *et al.* 1988; Perera and Perez-Mellado 2004; Schofield *et al.* 2008; Sacchi *et al.* 2010; Knox *et al.* 2013).

The body shape and size of a reptile can limit the options available for individual identification (Plummer and Ferner 2012). This is particularly the case for the Striped Legless Lizard *Delma impar*, which has an average snout-vent length of 79 mm (Coulson 1990) and is 'slightly thicker than a pencil' (Webster *et al.* 1992). The tail is approximately twice the snout-vent length but can be voluntarily cast off by the lizard (Coulson 1990), there is no external evidence of forelimbs and the rear limbs have been reduced to small flap-like appendages (Greer 1989).

The Striped Legless Lizard is listed as a threatened species by the IUCN, the Commonwealth of Australia, and all the states in which it occurs (Smith and Robertson 1999). Its distribution lies within the temperate lowland grasslands of south-eastern Australia (Coulson 1990), much of which has been lost as a result of urban, industrial and agricultural development (Kirkpatrick *et al.* 1995; Williams *et al.* 2005). Although the distribution and general habitat requirements of the species are becoming better understood (Coulson 1990; Hadden 1995; Dorrough and Ash 1999; Smith and Robertson 1999; Koehler 2004; Candy 2008; Maldonado *et al.* 2012; Howland *et al.* 2016), relatively little is known about basic life-history parameters such as reproductive success and longevity. Estimates of population size/growth, home range and movement patterns have been difficult to assess because of the cryptic nature of the species, a history of poor recapture success (within and between seasons) (Rauhala 1997; O'Shea 2005) and unreliable methods for identifying individual animals.

Previously, methods that have been used to mark Striped Legless Lizards include freeze-branding (Dorrough 1995) and pyrobranding (Kutt 1992; Nunan 1995; Hadden 1998; O'Shea 2005), and the use of Visible Implantable Elastomer (VIE) has also been unsuccessfully attempted (pers. obs.) The requirement for specialised equipment (e.g. liquid nitrogen) makes freeze branding difficult to apply in the field (Ekner *et al.* 2011), and although this method has been used for Striped Legless Lizards, its efficacy has not been evaluated.

Generally, pyrobranding for marking individual reptiles is considered to be a useful method, resulting in unambiguous identification of individuals (Ehmann, 2000; Winne *et al.*, 2006; Vervust and Van Damme, 2009; Ekner *et al.*, 2011). However, Hitchmough *et al.* (2012) reported that brands on Copper Skinks *Oligosoma aeneum* faded very rapidly, and a similar phenomenon has been observed in a captive population of Striped Legless Lizards, with husbandry notes reporting the loss of brands in as little as four months (pers. obs.). An alternative method for identifying individual Striped Legless Lizards is required.

One potential option for permanently marking Striped Legless Lizards is the use of Passive Integrated Transponders (PIT chips). PIT chips are widely applied in the study of wildlife, notably including hatchling Texas Horned Lizards *Phrynosoma cornutum* with snout-vent lengths as short as 20 mm (Henke 2008). If PIT chips could be safely implanted into Striped Legless Lizards, they would provide a permanent and reliable means of individual identification. Potential additional benefits of the use of PIT chips may include a reduction in handling associated with individual identification, especially if the chips could be detected through coverboards (roof tiles) that are commonly used to survey for Striped Legless Lizards. Such an approach has previously been described for the California Legless Lizard *Anniella pulchra* (Kuhnz 1999) and could potentially result in increased rates of detection and collection of habitat utilisation data for Striped Legless Lizards. Further investigation is required to determine if PIT chips can be successfully used in the identification of individual Striped Legless Lizards.

The use of lepidosis, that is the analysis of the arrangement and character of scales of reptiles, has previously been used for the identification of Green Iguana *Iguana iguana* (Rodda *et al.* 1988), Loggerhead Sea Turtles *Caretta caretta* (Schofield *et al.* 2008), the Common Wall Lizard *Podarcis muralis* and Western Green Lizard *Lacerta bilineata* (Sacchi *et al.* 2010). For a species such as the Striped Legless Lizard, investigation of the use of lepidosis for individual

identification is valid, given the limited availability of identification techniques for reptiles of this size, body form and cryptic nature.

Methods

Exploration of unique identifying features for Striped Legless Lizards

Between January and March 1999, 72 Striped Legless Lizards were collected for examination from Iramoo Wildlife Reserve, St Albans, Victoria, Australia (37°44'S, 144°47'E) and then released at the point of capture. For each of these lizards, photographs of the scale pattern were taken at each of the following points:

- Loreal region (pre/postoculars, loreals, supralabials and infralabials)
- Ventral head scales (mental, postmentals, chin shields and gulars)
- Dorsal head scales (rostral, nasals, prefrontal, frontal, supraoculars, parietals and nuchals)

Of these, the dorsal head scales displayed the greatest variation and were easiest for the examiner to make visual comparisons between individual animals (refer to Results).

Ontogenetic changes and persistence of patterns over time

To assess for ontogenetic changes in the dorsal head scale pattern of Striped Legless Lizards, a captive colony of eight hatchlings was studied for approximately two years. The animals hatched in autumn 2013, and the first dorsal head scale patterns were recorded on 27 March 2013. Subsequent images were recorded on 7 November 2013, 19 November 2014 and 12 February 2015. Thus, four separate images were recorded for each individual. Dorsal head scale images were recorded using a hand-held digital camera (e.g. Canon PowerShot 3S IS or Nikon COOLPIX P510) set to high resolution with the macro function turned on.

A captive colony of 52 adult Striped Legless Lizards housed at Victoria University was studied to determine whether the use of dorsal head scales for individual identification was reliable and persistent over time. Of these, 18 individuals were periodically photographed on up to six occasions over a 30 month period, with at least a six month period between photo events. Grey-scale photographs were taken using a digital video camera (Dage-MTI CCD100) mounted on a Zeiss Stemi 2000-C dissecting microscope. The in-built lamp on the microscope provided lighting from above, and a portable Olympus TL2 microscope lamp provided additional light from the side. The video camera was linked to the computer program Scion Image. Images were saved as bitmaps using a unique individual identification number assigned to each animal.

Identification accuracy

To test the accuracy of the dorsal head scale identification method, five volunteers were enlisted to take part in a blind study. All volunteers had a science degree with honours qualifications and worked in conservation biology. The volunteers were given a brief (approximately 15 minutes) training session using images from a separate catalogue of Striped Legless Lizard dorsal head scale photographs. The training session provided a description of the anatomy of the dorsal head scales and used examples to highlight identifying features.

From the Victoria University captive colony (see above), a subset of 18 individuals and 63 images were used for this study (Table 1). Each of the images for any given individual animal was recorded from separate monitoring sessions of the captive colony. Each image was assigned a random and unique number that corresponded to the individual animal (the corresponding information was not provided to the volunteers). Images, along with the corresponding random number, were printed onto individual sheets of A4 paper and shuffled to randomise their location in the pile. The volunteers were required to compare every image with every other image and place images of the same individual into discrete piles. The volunteers were not informed about how many individuals had been photographed but were informed that the number of images per animal was variable (no information about the highest or lowest number of images per animal was disclosed).

At the completion of identification and sorting, the volunteers were assessed on a number of criteria:

- The number of individuals identified—i.e. the number of discrete piles of images;

Table 1. The number of animals for which there was either a single image or a group of four, five or six images for comparison with the overall set of images.

Number of images for comparison	Number of individual animals	Total images
1	6	6
4	6	24
5	3	15
6	3	18
Total	18	63

- The number of correct groupings of each individual animal—i.e. the number of piles of images that contain all the correct images;
- The number of split groups—this measure accounted for the number of animals for which all images were not correctly matched because some images had been assigned to a different pile;
- The number of combined groups—this measure accounted for the number of animals for which some images had been incorrectly assigned to the wrong pile.

For each volunteer, eight of the 63 images were randomly selected *a priori* in order to determine whether they had been correctly identified. Each image was taken to be correctly assigned if it was grouped with the majority of other images for the individual animal.

For each of these five measures, the arithmetic mean of the results from the five volunteers was calculated. This mean was also expressed as a proportion of the true values for each of the five measures. Ninety-five percent confidence intervals were calculated using a t-value of 2.776 (two-sided) for the measure *the number of individuals identified*; and a t-value of 2.132 (one-sided) for all other measures.

Results

Dorsal head scales are useful for individual identification

Of the three regions of scales explored (loreal, ventral head and dorsal head), the arrangement and pattern of dorsal head scales was found to be sufficiently varied between Striped Legless Lizards to enable individual identification. A typical arrangement of dorsal head scales is presented in Fig 1. Using this typical dorsal head scale arrangement as a basis for comparison, a combination of the shape of the enlarged parietal shields (Fig. 2); the number, shape and arrangement of nuchal scales immediately posterior to the parietals (Fig. 3); and variations in the frontal (Fig. 4) and prefrontal scales (Fig. 5) could be used to differentiate between animals, and also for individuals to be positively identified.

Anecdotally, individual animals can also be identified from their slough (shed skin) if the dorsal head scales have been shed intact (Fig. 6).

Ontogenetic changes and persistence of patterns over time

The pattern of dorsal head scales of all eight hatchlings in the Zoos Victoria captive colony remained constant for at least two years after hatching. All eight individuals were positively

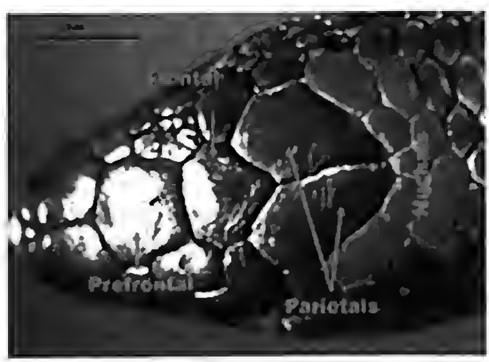

Fig. 1. The 'typical' shape and arrangement of the prefrontal, frontal, parietal and nuchal scales in Striped Legless Lizards.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 2. Examples of variations in the shape and arrangement of parietal scales.

Fig. 3. Examples of variations in the shape and arrangement of nuchal scales. The circles indicate scales that are sufficiently different from the 'typical' arrangement to serve as an initial point of attention and comparison.

Fig. 4. Examples of variations in the shape of frontal scales.

Fig. 5. Examples of variations in the shape of prefrontal scales.

Fig. 6. Individual Striped Legless Lizards can be identified from sloughs that have been shed under refuges in their habitat.

Fig. 7. A few weeks after hatching, this Striped Legless Lizard had a 49 mm snout-vent length on 27 March 2013 and grew to a snout-vent length of 68 mm by 19 November 2014. During this time the dorsal head scale pattern remained consistent.

The use of dorsal head scale patterns was a reliable method for identifying and monitoring adult Striped Legless Lizards in the captive colony at Victoria University. On some monitoring occasions, the dorsal head scales had been injured and identification was limited to a process of elimination based on morphometrics and enclosure number. Mostly, these injuries were superficial and tended to repair to the original dorsal head scale arrangement, and thus animals could be individually identified using this method in subsequent monitoring sessions (Fig. 8).

Fig. 8. Damage to the parietal and nuchal scales was observed on this adult Striped Legless Lizard in the captive colony at Victoria University approximately one year after it was first photographed. Approxi-

Table 2. The outcomes of identification of individual Striped Legless Lizards by trained volunteers (n=5 volunteers). CI LL = Confidence Interval Lower Limit; CI UL = Confidence Interval Upper Limit.

	Mean	95% CI LL	95% CI UL	Proportion of total
Number of groups identified out of 18	21.2	18.4	24.0	118%
Number of correct groups out of 18	13.4	11.8	15.0	74%
Number of split groups out of 18	4.4	2.4	6.4	24%
Number of groups combined out of 18	1.6	0.3	2.9	9%
Correct identification of 8 images	7.2	6.4	8.0	90%

Identification accuracy

Volunteers were generally able to positively identify individual Striped Legless Lizards using the dorsal head scale pattern. Based on a random *a priori* selection of eight images, on average volunteers were able to correctly group 90% of these images with the majority of other images for the individual animal. The level of correctly identified individuals was lower (an average of 74% of images were correctly grouped) when the entire catalogue of 63 images was considered. This was largely due to the volunteers tending to separate out images when there was uncertainty, resulting in a greater number of individual animals being identified than existed—the mean number of individuals identified was 21.2, when the true number was actually 18. The volunteers infrequently combined groups of images (9% of images incorrectly assigned to a group) and often this involved a single image from one individual being incorrectly assigned to the group of images for a different individual (Table 2).

Discussion

The dorsal head scale patterns of Striped Legless Lizards are sufficiently varied between individuals to enable the use of lepidosis (the analysis of the arrangement and character of scales of reptiles) for individual identification. This method of individual identification meets the criteria of being simple, accurate, durable and inexpensive, and is unlikely to interfere with behaviour, growth or survival. The use of this method does not preclude investigation into other technologies such as Passive Integrated Transponder (PIT) tags or Visible Implantable Elastomer (VIE) which may more satisfactorily meet the criteria for selection of a marking method.

Durability

The dorsal head scale pattern of Striped Legless Lizards appears to be fixed from the time of hatching and alters very little with ontogenetic development or over time. In this study, animals that suffered damage to the head scales tended to heal to the original pattern; however, it is conceivable that this may not always be the case, especially if the damage to scales is severe. The use of dorsal head scales for individual identification of Striped Legless Lizards has greater durability than the previously used method of pyrobranding. Anecdotal records from the captive colony used in this study document that pyrobrand marks were beginning to fade in as little as four months, and had completely disappeared from one animal after 13 months. Thus, increasingly, the identification of individuals within the captive colony was dependent on the use of dorsal head scale patterns.

This identification method could also be extended to the examination of intact sloughs (both in captivity and in the field)—an approach used by Henley (1981) in the individual identification of snakes.

Simplicity and Accuracy

Conceptually, the use of lepidosis is relatively simple and requires only a digital camera with macro function. However, manual processing of images is time-consuming, especially when the catalogue becomes large. In some instances, early image-recognition programs were considered to be less time efficient (and potentially less accurate) than manual matching (Lettink 2012). However, these programs were useful for restricting the number of potential matches that could subsequently be assessed by humans (Lettink 2012), especially when processed in

conjunction with additional information such as point of capture and morphometric data (e.g. Stamps 1973; Rodda *et al.* 1988; Gamble *et al.* 2008). Recent advances in image recognition software have reduced processing time and increased accuracy (Sacchi *et al.* 2010, Duyck *et al.* 2015) and should be explored for this species. Care is required to ensure that images are of sufficient quality (lighting, focus, angle, resolution) for the purpose of individual identification, and more recently a background grid has been incorporated to enable accurate measurements of scales.

Overall, volunteers with only a small amount of training were able to achieve reasonable levels of accuracy using the dorsal head scale pattern mapping method. Although further training and/or practice is likely to increase the accuracy of volunteers, significant improvements are likely to be achieved when additional data, such as point of capture and morphometrics of each animal, are incorporated into the process of image evaluation.

Animal welfare

The use of dorsal head scale patterns for the recognition of individual Striped Legless Lizards is a non-invasive method. In the field, use of a digital camera with a macro function enables photographs to be acquired quickly, thus potentially reducing the period of capture and handling (Knox *et al.* 2013) when compared to previously used marking methods.

Using this method, the collection of longitudinal field-data on Striped Legless Lizards requires both recapture and subsequent handling—activities that may induce stress (Langkilde and Shine 2006). Presumably the stress associated with recapture and handling required for individual identification using dorsal head scale patterns is no greater than the stress associated with recapture and handling for the application of the previously used methods of pyrobranding and freezebranding. Most studies suggest that there are few animal welfare issues associated with pyrobranding (Ehmann 2000; Winne *et al.* 2006; Vervust and Van Damme 2009; Ekner *et al.* 2011). However, Hitchmough *et al.* (2012) express ethical concerns about the technique, especially when multiple brands are applied to small lizards.

Recapture success

Anecdotally, the use of pyrobrands for individual identification in the captive colony was not associated with infections at the pyrobrand site or directly attributed to mortality—records indicate that 90% of the animals were still alive and healthy six months after branding. Thus, presumably low rates of recapture in field studies (O'Shea 2005) were not a result of mortality associated with the pyrobranding process.

Interestingly, recent field studies that have adopted the dorsal head scale pattern method of individual identification only (no pyrobranding) have recorded similar rates of recapture (i.e. <10%) to studies where only pyrobranding or a combination of both methods was used. Thus, although the dorsal head scale pattern mapping method meets many of the criteria for individual identification, it seems that it is unlikely to lead to any change in the recapture success for this species.

Summary

Lepidosis using the dorsal head scales is a useful method for the identification of individual Striped Legless Lizards. This method meets many of the fundamental criteria for individual identification in that it is durable, reasonably accurate, inexpensive and unlikely to interfere with behaviour, growth or survival. The method is unlikely to have any greater effects on recapture rates (positive or negative) than the previously used method of pyrobranding. Manual application of this method is useful for small catalogues of dorsal head scale images but development of this technique into an automated system is required for larger catalogues of images.

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Searching for the Grassland Earless Dragon *Tympanocryptis pinguicolla* in western Victoria

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Abstract

The Grassland Earless Dragon *Tympanocryptis pinguicolla* is a threatened species restricted to natural temperate grasslands of south-eastern Australia. The species has undergone significant decline across much of its range, with the last confirmed sighting in Victoria in 1969. We undertook targeted surveys in suitable habitat in western Victoria with the aim of detecting any remaining populations. Remote sensor cameras (Reconyx HC500) were deployed at a total of 14 sites across two seasons from October 2014 to February 2015, and from February to March 2016 (total of 3950 camera-trap-days). No Grassland Earless Dragons were detected. The absence of a confirmed sighting of the species in Victoria for 48 years suggests that there is a high likelihood that it may be extinct in Victoria. However, the lizard's small size and its cryptic behaviour mean that the possibility of locating a remnant population cannot be discounted entirely. Accordingly, Zoos Victoria is now working with the Corangamite Catchment Management Authority and local community to identify any potential sightings of the species by the public. (*The Victorian Naturalist*, 134 (6), 2017, 187–198)

Keywords: Grassland Earless Dragon, extinction, surveys, temperate grassland, communities

Introduction

Australia's natural temperate grasslands and grassy woodlands have experienced extensive clearing and loss since European settlement, and lowland native grasslands of the south-east are considered Australia's most threatened ecosystem (Kirkpatrick *et al.* 1995). Natural Temperate Grassland of the South Eastern Highlands and the Victorian Volcanic Plain are nationally listed as Critically Endangered Ecological Communities (*Environment Protection and Biodiversity Conservation Act 1999* [EPBC]). Conservation and management of these habitats has been the subject of much attention in recent decades (McDougall and Kirkpatrick 1994; Williams *et al.* 2013).

Loss and modification of native temperate grasslands has had a profound impact on animal and plant populations, with many species reliant on these habitats now listed as threatened (Antos and Williams 2013). The Grassland Earless Dragon (GED) *Tympanocryptis pinguicolla* (Fig. 1) is one such species, as it is restricted to natural temperate grasslands (Stevens *et al.* 2010). Historic records indicate that it used to occur from Bathurst in NSW, south through the ACT and the Monaro region in the Southern Tablelands, to the basalt plains north and west of Melbourne in Victoria (Robertson and Evans 2009). The species has undergone a significant decline and now occurs in <5% of its former range (Kirkpatrick *et al.* 1995; Robertson and Evans 2009; Diamond *et al.* 2012). Extant populations are currently known from just two geographic areas, one in the ACT and neighbouring Queanbeyan district in NSW and the other in the Monaro region of NSW. These populations are considered to comprise distinct genetic units (Carlson *et al.* 2016). The species is nationally listed as Endangered (EPBC).

In Victoria, the species is listed as Threatened under the *Flora and Fauna Guarantee Act* (*FFG*) 1980, and as Critically Endangered on the *Advisory List of Threatened Vertebrate Fauna in Victoria* (DSE 2013). The last confirmed record of this species in Victoria was in 1969 in the Geelong area (Pescott 1969). Despite many subsequent surveys using an array of survey methods (Clemann *et al.* 2013), and some unconfirmed sightings, the species has not been confirmed in Victoria since that time (Robertson and Evans 2009). Additionally, numerous surveys in Victoria for the Striped Legless Lizard *Delma impar* that were carried out in areas and habitat in which *T. pinguicolla*

Fig. 1. Grassland Earless Dragon *Tympanocryptis pinguicolla*. Photo. P Robertson.

could occur, also failed to locate any Grassland Earless Dragons (Smith and Robertson 1999; Robertson *et al.* 2010; Sofo 2011; Smith 2012; McCutcheon and Westcott 2012; G Peterson, pers. comm.).

The Victorian population is quite likely be to a distinct species from those found in the ACT and NSW (Melville *et al.* 2007). However, this has not been confirmed to date because it has not been possible to extract DNA samples of adequate quality from any preserved Victorian individuals to permit analysis (Melville *et al.* 2007).

Previous field surveys for this species have employed a range of techniques: rock rolling, pitfall trapping, artificial shelter sites ('spider burrows'—often covered to provide shade), and examination of burrows and cracks in the soil using an endoscope (McGrath *et al.* 2015; Robertson *et al.* 2010). More recently, remotely-triggered cameras (camera-traps) have been used to detect small reptiles in the field. Welbourne (2013) successfully trialled passive infrared cameras to detect *Amphibolurus muricatus* and small skinks, *Lampropholis* spp., in coastal NSW. Motion-sensor cameras were used successfully to detect *T. pinguicolla* in NSW (McGrath *et al.* 2012; R Pietsch, pers. comm.). The most recent survey for *T. pinguicolla* in Victoria also used camera traps and funnel traps to survey volcanic grasslands between Melbourne and Geelong in April 2013 (Clemann *et al.* 2013).

Zoos Victoria is a zoo-based conservation organisation with a mission to 'secure a future rich in wildlife' (Zoos Victoria 2016). One of its primary objectives is to prevent the extinction of critically endangered Victorian terrestrial vertebrates and support their recovery in the wild (Zoos Victoria 2014). The main operational mechanism to achieve this objective is the Fighting Extinction program that covers 21 threatened species, 17 of which occur in Victoria.

The Grassland Earless Dragon is one of the Fighting Extinction species and in 2013 Zoos Victoria allocated research funding to investigate the possibility that the Grassland Earless Dragon was still extant in Victoria. Here we report on the outcome of these surveys, undertaken at 14 grassland sites west of Melbourne, Victoria.

Methods

Camera-trap Trial

To assess the effectiveness of cameras at reliably detecting *T. pinguicolla* in the field, a trial was carried out in an outdoor service area of Melbourne Zoo's Reptile House on 11 and 12 October 2014. No *T. pinguicolla* were available, so the trial used three juvenile *Pogona henrylawsoni* that were similar in size to adult *T. pinguicolla* (55–65 mm SVL). The three lizards were placed in a single timber-framed box with mesh front and top, measuring 1.0 m long x 0.5 m wide x 0.6 m high. A remote sensor camera (Reconyx HC500 HyperFire Lo-Glow Semi Covert IR) was positioned above and facing down towards the base of the box to detect lizards when they passed through its sensor field at a distance of 40–50 cm. A closed-circuit digital camera (Capture Model VD-IR30VF 1/3" Vandalproof IR Varifocal Dome Camera) connected to a digital video recorder (GANZ Model DR16HL Digimaster Series 16CH) was also installed to record for the entire duration of the trial on both days.

The three *P. henrylawsoni* were placed in the box from 1430 to 1630 hrs on 11 October and from 1200 to 1630 hrs on 12 October. They were encouraged to move by placing food items—live captive-bred crickets—in the box. One or more lizards entered the focal area of the Reconyx camera on eight occasions on 11 October and on nine occasions on 12 October. They were detected by the Reconyx five and seven times respectively.

The camera-trap trial at Melbourne Zoo using *P. henrylawsoni* as a surrogate species confirmed that remote cameras can reliably detect lizard presence and enable species identification. This finding is consistent with that from several recent studies (McGrath *et al.* 2012; Clemann *et al.* 2013), and hence cameras were deemed to be an appropriate survey technique.

Site Selection

To guide identification of prospective areas for surveys for *T. pinguicolla* in Victoria, historical records of the species were examined. From those records that were considered plausible, a presence-only species distribution model for *T. pinguicolla* for Victoria and surrounding areas, including the ACT and the Monaro Tablelands in NSW, was created. For details on the methods used see Liu *et al.* (2013). In addition, we created a presence-only model of indigenous grasslands using the same methods as Papas *et al.* (2016) for modelling the distribution of seasonally herbaceous wetlands, using both site observations of the ecosystem and temporal Landsat summaries. These two spatially explicit models were aggregated at a pixel resolution of 25 m by calculating their geometric mean to produce a putative index of the likelihood of Grassland Earless Dragon persistence. Expert knowledge on likely habitat use by *T. pinguicolla* was also incorporated. The resultant index was then further perused, along with ancillary spatial data on geology, land use, soil sodicity and soil depth (rockiness) to identify candidate sites for camera trapping and active searching.

The inclusion of consistent 'lack of greenness' in the initial modelling to guide identification of prospective survey areas was based on the assumption that native grassland plus 'not very green' represents rocky or open grassland likely to be suitable for *T. pinguicolla* (N Clemann and P Robertson, pers. obs.).

Seven broad areas in Victoria were identified as potentially supporting suitable habitat (Fig. 2), with a preliminary assessment of these prioritising areas 1, 2, 3, 4 and 6 for further examination. These areas were visited, and survey sites were selected based on a ground inspection of habitat suitability, ease of access and camera security. The other two broad areas (i.e. 5 and 7) were not considered further due to the practicalities of undertaking surveys there and expert knowledge of those areas indicating a lower likelihood of lizards being present.

Survey Locations and Periods

Fourteen sites were selected for surveys for *T. pinguicolla* (Table 1; Fig. 3). All were on private property except for Sites 2 (Department of Environment, Land, Water and Planning [DELWP]), 13 and 14 (Melbourne Water Western Treatment Plant [MWWTP]), which are on state government land. At each site (or sub-site), five remote sensor cameras (Reconyx HC500 HyperFire Lo-Glow Semi Covert IR) were deployed, 50–200 m apart. Cameras were left in position for at least 14 days, but at some

Fig. 2. Areas in Victoria with habitat potentially suitable for *Tympanocryptis pinguicolla* (darker shades of blue denote areas that are more likely to support grassland habitat suitable for this species).

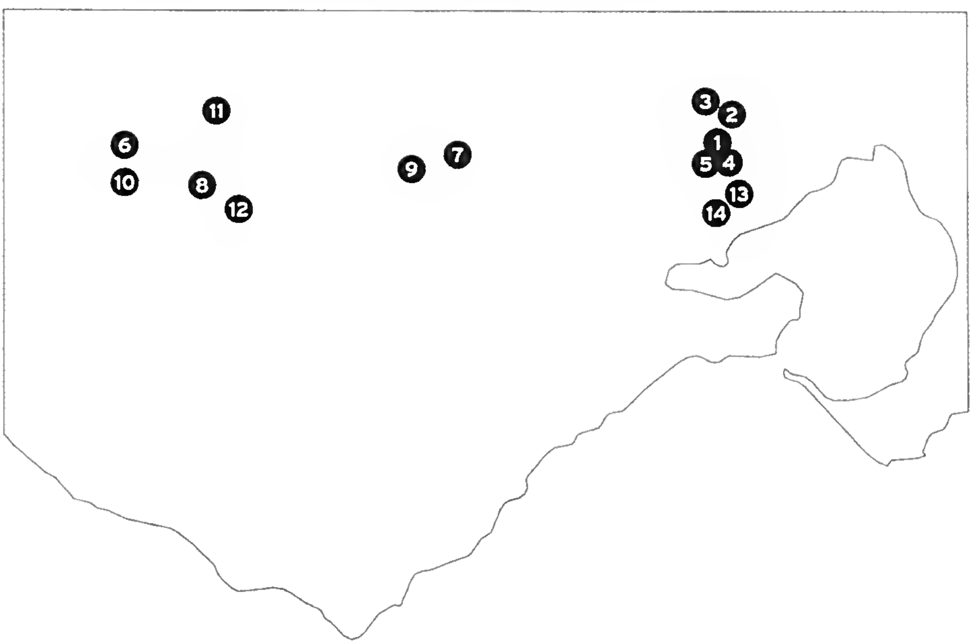

Fig. 3. General localities in western Victoria for the 14 sites where remote sensor cameras were deployed to detect *Tympanocryptis pinguicolla*.

Table 1. General locations, habitat and survey effort for *Tympanocryptis pinguicolla* in western Victoria

Site No./Area	General site location	Survey period	Habitat	Survey effort (number of camera days)
1 (A and B)/6	West of Werribee	October 2014 –January 2015	Cameras in predominantly native vegetation on rocky knolls, at slightly higher elevations than the surrounding property, which supported mainly exotic vegetation on land previously cultivated or subjected to widespread herbicide application. Sheep were present.	295
2 (A and B)/6	West of Werribee	October 2014 –January 2015	Consistently thick, mixed native and exotic vegetation cover over the entire plot, with no grazing (Fig. 4).	405
3 (A and B)/6	West of Werribee	October 2014 –January 2015	Flat to gently sloping, mixed native and exotic grassland, with intermittent grazing by sheep and cattle.	315
4 (A and B)/6	West of Werribee	October 2014 –January 2015	Moderate to heavily grazed, predominantly native grassland. Sheep were present (Fig. 5).	345
5 (A and B)/6	West of Werribee	October 2014 –January 2015	Land sloped to east bank of Little River, with predominantly native grassland cover (Fig. 6).	335
6 (A and B)/2	Near Dundonnell, western Victoria	January –February 2015	Extremely dense rock cover with grazed sparse native grasses (Fig. 7).	550
7 (A and B)/2	Between Rokewood and Shelford, western Victoria	January –February 2015	High quality native grassland remnants with moderate rock cover. Sheep and cattle were present.	560
8/3	Near Derrinallum, western Victoria	February – March 2016	Very rocky cattle property with predominantly introduced plants.	220
9 (A and B)/4	East of Rokewood, western Victoria	February – March 2016	Mainly native grassland with some introduced plant cover, extensive rocky knolls. Light grazing by sheep.	330

Table 1. Cont.

Site No./Area	General site location	Survey period	Habitat	Survey effort (number of camera days)
10/2	Near Darlington, western Victoria	February to March 2016	Heavily grazed rocky knolls with some native grassland remnants.	70
11/1	Near Mingay, western Victoria	February to March 2016	Rocky knolls with mixed native and introduced grassland plants.	70
12/3	South of Lismore, western Victoria	February to March 2016	Heavily grazed rocky knolls with mixed native and introduced grassland plants.	65
13 (A and B)/6	South-west Werribee	February to March 2016	Mainly native plant cover with some weeds and few rocks.	130
14 (A and B)/6	South-west Werribee	February to March 2016	Mainly native grassland, with some exotics, and extending to saltmarsh margin. Some rocky knoll habitat.	260

locations for up to 40 days. Where sub-sites were utilised (designated 'A and B' above), the five cameras were either moved to the second sub-site after the initial survey period at A, or the two sub-sites were sampled concurrently.

Camera Installation

At each camera location, an area of ground approximately 5.0 m long and 0.6 m wide was cleared of vegetation using a brush-cutter, to ensure no impediment to lizard movement and to avoid cameras being triggered by moving vegetation. The cameras were mounted on wooden stakes using a short adjustable arm and positioned 55–65 cm above ground, facing vertically downwards above an artificial 'spider burrow'.

The spider burrow was a 14.5 cm long piece of poly pipe, with a narrower removable length of poly pipe (approx. 2.1 cm internal diameter, with a roughened inner surface) fitted snugly inside the outer pipe. These were oriented vertically and buried level with the soil surface. On either side of the artificial burrow, a 2 m length of 30 cm high flywire drift fence was fixed in place in an east-west alignment and tightened to prevent movement by wind. Each 2 m length of drift fence ended about 15 cm from the burrow, creating a 30 cm gap in the middle where the artificial spider burrow was located. At some extremely rocky sites it was not possible to erect the drift fence.

The Reconyx HC500 cameras were set to take three images upon each trigger event. Additionally, the cameras were programmed to take an image every minute between 9 am and 6 pm using the time lapse function.

All camera locations were recorded using a Garmin GPS76CSx. They are not included here for privacy purposes.

Habitat Variables

Nine habitat variables were recorded by rapid visual assessment at each of the camera locations at all sites: % total grass cover, % native grass cover, % introduced grass cover, % bare ground, % rock cover, % other cover and three categories of dominant vegetation height %≤ 150 mm, % 150–500 mm and % ≥ 500 mm (Appendix 1). Assessments were made over an area of approximately 0.01 ha at each camera location.

Image Analysis
Images from each camera location were examined for the presence of *T. pinguicolla*. All vertebrate fauna species were noted and identified where possible.

Three cameras were disturbed by cows and sheep at Sites 2 and 5, and four cameras at Sites 4 and 5 recorded images at night. Just over 21 500 images were affected, all of which were excluded from the total images scanned for presence of *T. pinguicolla*. All these were single cameras within the groups of five cameras deployed at each site. At Site 5, camera 5B was stolen during the second deployment.

A prototype program developed at the School of Architecture & Design at RMIT University, Melbourne, to automatically read camera images, was trialled. The program first looked for differences between adjacent images and evaluated those differences to find shapes over a specified size. Identified shapes were highlighted with a red bounding box and the image saved to a new 'processed' folder within the folder of images being scanned. The image recognition program was trialled on 20 000 images from the 2014/15 surveys, with approximately 5000 images identified for further examination. These images also were checked visually for presence of *T. pinguicolla*. The program did not detect any *T. pinguicolla*. Its application proved to be more time-consuming than visually scanning images and it was discontinued. However, further refinement of the technique may prove useful in scanning large sets of images.

Manual Searches
A second DELWP grassland plot, close to Sites 1 and 2, was examined by eight people for three hours from 8 am to 11 am on 17 November 2014. All available cover, predominantly rocks, was turned and checked for the presence of lizards sheltering beneath.

Fig. 4. Remote camera and drift fence at Site 2 (note thick grass cover). Photo. R Hammond.

Fig. 5. Heavily-grazed area at Site 4. Photo. R Hammond.

Fig. 6. More open habitat with exposed rocks at Site 5. Photo. R Hammond.

Results
Field Results
More than 2.3 million images were recorded by the cameras at the 14 sites for the combined survey effort during 2014/15 and 2016.

The detection rate of reptiles was exceedingly low. Grassland Earless Dragons were not detected at any site in any of the surveys. Three other reptile species were recorded: three individuals of the Common Blue-tongued Lizard *Tiliqua scincoides*, one Eastern Tiger Snake *Notechis scutatus* (juvenile) and two Eastern Large Striped Skink *Ctenotus spaldingi* (Fig. 8).

Small numbers (<10 individuals of each species) of other native vertebrate species were also photographed. These included Australian Magpie *Gymnorhina tibicen*, Magpie-lark *Grallina*

Fig. 7. Very rocky habitat at Site 6. Photo. R. Hammond.

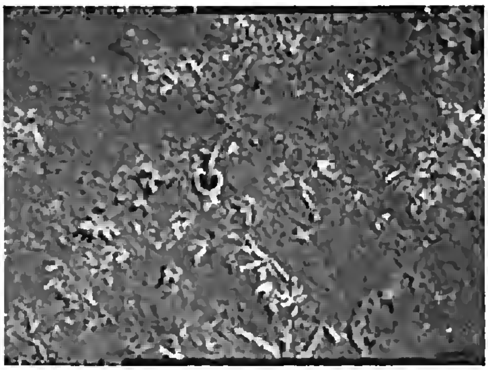

Fig. 8. Eastern Large Striped Skink *Ctenotus spaldingi* recorded at Site 8.

cyanoleuca, Brown Quail *Coturnix ypsilophora* and Willie Wagtail *Rhipidura leucophrys*. Eastern Grey Kangaroo *Macropus giganteus* and Short-beaked Echidna *Tachyglossus aculeatus* were the only native mammals recorded. One frog was detected at night, but identification was not possible.

Non-native mammals (feral cat, House Mouse, sheep, cow and rabbit) were also recorded, again in small numbers.

Large numbers of millipedes, ants, spiders, grasshoppers, butterflies and wasps were recorded, but none of these was identified to genus or species.

Manual searches

More than 1650 rocks were examined during the day of rock-rolling at the second DELWP grassland plot in November 2014. Weather conditions were cool, with full cloud cover and maximum of ~15°C, and no *T. pinguicolla* were located. A range of invertebrates was found (unidentified ants, millipedes, etc.), but only one vertebrate species was encountered—three individuals of Spotted Marsh Frog *Limnodynastes tasmaniensis*.

Opportunistic rock-rolling close to some camera sites during the 2016 surveys detected single individuals of Fat-tailed Dunnart *Sminthopsis crassicaudata*, Eastern Large Striped Skink *C. spaldingi* and Bougainville's Skink *Lerista bougainvillii* under rocks.

Discussion

All historical records of *T. pinguicolla* in Victoria are from grassland areas between Melbourne and Geelong. Information on the characteristics of 'preferred' habitat for this study was based upon observations of extant populations in NSW and the ACT. There, the species occurs mainly in open or short, sparse grasslands, with or without rocks, often with a history of light grazing (Osborne *et al.* 1993). The inclusion of consistent 'lack of greenness' in the initial modelling to guide identification of prospective survey areas was based on the assumption that native grassland plus 'not very green' represents rocky or open grassland, which *T. pinguicolla* is considered to prefer (Osborne *et al.* 1993; Nelson *et al.* 2000; Dunford *et al.* 2001; R Pietsch, pers. comm.).

Grasslands adjoining saline habitats were also investigated, as some historical records of *T. pinguicolla* are from such situations in Victoria, and the closely-related *T. lineata* is known to use saline shrublands/grasslands in northwestern Victoria (Robertson *et al.* 1989).

Surveys to detect *T. pinguicolla* are best carried out from late spring until mid-autumn, when conditions are warm to hot and lizards are most active. The surveys undertaken here were initially timed to detect lizards during the early breeding season (September to October) when males are considered to be most active, and mid-late summer (February to March) when hatchlings and young lizards are expected to be present and local abundance may peak (Robertson and Evans 2009). The first survey (October to November 2014) was carried out later than planned, but the delay was unlikely to have negatively affected the likelihood of

detection, as weather conditions were cool and overcast for much of the preceding period. Active lizards have been observed above ground in mid-June in the ACT (Nelson 2004), and are also reported to be more active when temperatures exceed 24°C (R Pietsch, pers. comm.).

Much of the habitat encountered at Sites 1 to 5 was native grassland with low floristic species diversity. Some areas were heavily weed-infested, such as the site that was hand-searched, whilst Site 2 had very dense grassy vegetation resulting from a lack of recent grazing, making it potentially unsuitable for *T. pinguicolla*. The other sites in this group were either currently or recently grazed, and the resultant structure of the habitat appeared suitable for *T. pinguicolla*. All five sites west of Werribee, and the rock-rolled land, are within the larger of the two proposed Western Grassland Reserves, and are therefore relevant to the Melbourne Strategic Assessment process (DSE 2009).

Sites 6 and 7, north-west of Geelong, supported habitat of a generally suitable structure, although the raised rocky knolls at Site 6 were too rocky to install drift fences, potentially inhibiting detections. In particular, Site 7 appeared to be most suitable for *T. pinguicolla*, with rocky areas and relatively short, open native grassland maintained by light grazing. Similar sparse grassland patches were observed east of Shelford, but were not examined during this study.

Extensive rocky rise areas dominated Sites 8 to 12, surveyed in western Victoria in 2016. All supported grassland of variable quality within the rocky areas, and usually had some grazing that maintained generally open vegetation structures, potentially suitable for *T. pinguicolla*. Adjoining lower areas were often dominated (when native) by tall tussock-forming species associated with wetter grasslands, and hence likely to be unsuitable for *T. pinguicolla* based on this denser vegetation structure. There are no historical records of *T. pinguicolla* from this region.

The two sites within the Western Treatment Plant (13 and 14) supported native grassland (with some exotic grasses) of a structure potentially suitable for *T. pinguicolla*. However, lack of grazing at these sites, as well as increased invasion by weeds, may result in a denser vegetation structure not suitable for this species.

The objective of these surveys was to determine if extant populations of *T. pinguicolla* survive in Victoria. The cameras used in these surveys detected a range of species, including invertebrates much smaller than this lizard. This, plus their effectiveness in the short trial at Melbourne Zoo, where a surrogate species (*P. henrylawsoni*) of similar size to *T. pinguicolla* was detected on motion and heat-activated cameras, suggests that the remote cameras are likely to have detected *T. pinguicolla* had this species been present in at least moderate abundance at the camera locations, as occurred on the Monaro Plateau in NSW (McGrath *et al.* 2012). Most of the sites also had large numbers of small invertebrates, including ants and small spiders, which are suitable food items for *T. pinguicolla*. However, these invertebrate faunas are likely to have been considerably altered since European settlement, and now have a predominance of exotic species. Food availability may be only one factor affecting the persistence of this species at a site; vegetation structure is likely to also have a major influence.

Some of the locations from the current study were close to sites of previous surveys for *T. pinguicolla*, the most recent being in April 2013 (Clemann *et al.* 2013). An earlier extensive and detailed survey effort was implemented in the Greater Geelong, Lara and Little River areas of western Victoria from 2009/10 to 2012/13 (G Peterson, pers. comm.), utilising monitoring grids with artificial spider burrows, rock-rolling, burrow examination with endoscopes, funnel traps and remote sensor cameras. These approaches were supplemented by circulation of a Grassland Earless Dragon fact sheet to landowners, council staff and the local community in the survey area. Prior to that, extensive surveys utilising spider burrows and small pit traps were conducted between 1994 and 1997 in the Greater Geelong, Little River, Sunbury and Donnybrook areas (Robertson and Webster, in prep.). None of these studies detected the species.

The failure to record *T. pinguicolla*, despite several highly targeted surveys during the past decade, raises doubt about whether populations of this species survive in Victoria. The failure to

detect the species during surveys at and near historic locations strongly suggests that it has become locally extinct across most of its Victorian range. Given the small size of the species and its use of shelter sites in the ground and at the base of grass tussocks, the possibility that one or more small populations persist undetected in remnant grasslands elsewhere in western Victoria cannot be discounted entirely, but the indications from this and other recent studies are not encouraging. Notably, extensive fauna surveys conducted throughout grasslands from Melbourne to western Victoria over the past 30 years have not detected *T. pinguicolla*.

Following these field surveys, Zoos Victoria is attempting to raise the profile of *T. pinguicolla* within a targeted area of western Victoria supporting potentially suitable habitat, in the hope that it may generate possible sightings from the public. This work builds on the strong working relationships formed with Corangamite Catchment Management Authority (CCMA) and local landholders during the field surveys.

Dragonsearch focuses on increasing awareness about *T. pinguicolla* at primary and secondary schools in the CCMA area. To date, 16 schools have registered for the program. Each has received a Dragonsearch pack that contains 'Missing' posters (Fig. 9), information on the lizard, materials to assist lizard identification, engagement materials such as masks, badges and collector cards, and suggestions for 'dragon-related' events that can be hosted by the school or within the local community. Although no *T. pinguicolla* records have been generated to date, the campaign has resulted in an individual of a related species, *Tympanocryptis lineata*, being photographed and reported in the Coorong region of south-east South Australia (B Sanders, pers. comm.). These engagements will be expanded over 2017 and 2018, and the campaign will be reassessed at the end of that period.

A similar community program was implemented for *T. pinguicolla* on the Monaro Plateau in 2014 (T McGrath, pers. comm.). Project Dragon was a successful collaboration between the private landowners, the 'Kosciuszko-to-Coast' partnership, the ACT Herpetological Association, Friends of Grasslands, the NSW Office of Environment & Heritage, and the University of Canberra's Institute for Applied Ecology (http://k2c.org.au/files/lauren_van_dyke/farmers_grasslands_dragons_final_for_webupload.pdf).

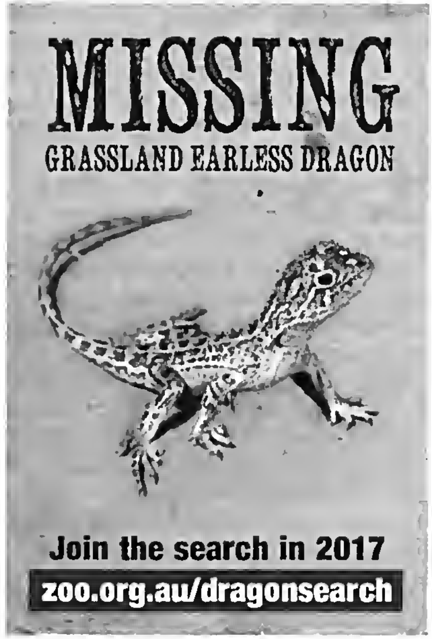

Fig. 9. 'Missing' poster for *Tympanocryptis pinguicolla* by Zoos Victoria with the Corangamite CMA.

Further north, Pittsworth District Landcare Group worked with the Queensland Parks and Wildlife Service on the Darling Downs to protect what was initially thought to be a population of *T. pinguicolla*. These lizards were subsequently described as two new species of *Tympanocryptis* (Melville *et al.* 2014; Hobson 2015).

There is increasing literature on the role of citizen science and the participation of local communities more generally in contributing to our knowledge base and protection of wildlife (Dickinson and Bonney 2012). The numerous Friends groups coordinated by the Victorian National Parks Association, the Field Naturalists Club of Victoria and Land for Wildlife are but three successful vehicles demonstrating that people care about wildlife and habitats and will transfer their interest into action if there are mechanisms to do so. Moreover, the Victorian government's latest Biodiversity Strategy (DELWP 2017) recognises that Victorians

value nature, which is a key step to improving our effectiveness at conserving biodiversity.

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Experienced staff and trained volunteers in the Wildlife Conservation and Science Department at Zoos Victoria examined images for the presence of Grassland Eearless Dragons.

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Appendix 1. Habitat variables at camera sites

Camera location	Total grass cover (% native/introduced)	% bare ground	% rock cover	Predominant vegetation height (mm)
Site 1 (A & B)	70 (50/50)	20	20	≤ 150mm
Site 2 (A & B)	90 (40/60)	10	20	150-500mm
Site 3 (A & B)	70 (55/45)	20	10–15	≤ 150mm
Site 4 (A & B)	60 (50/50)	25	10	≤ 150mm
Site 5 (A & B)	70 (30/70)	15	20	150-500Mm
Site 6 (A & B)	50 (40/60)	10	40	≤ 150mm
Site 7 (A & B)	60-80 (40/60)	5	15	≤ 150mm
Site 8	30 (0/100)	25	25–40	<150
Site 9 (A)	75 (80/20)	15	0–10	<150
Site 9 (B)	70 (100/0)	20	15	Similar across the three height categories
Site 10	15 (0/100)	35	45	<150
Site 11	30 (40/60)	25	30-70	<150
Site 12	50 (10/900	30	5-40	<150
Site 13 (A & B)	60 (75/25)	35	5-10	<150
Site 14 (A & B)	75 (55/45)	10	5-60	≤150

Observations of Black Snakes *Pseudechis* in captivity, with notes on reproduction and longevity

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Abstract
Information on the successful husbandry and captive breeding of the black snakes *Pseudechis* is provided. Basic reproductive data including gestation, fecundity, incubation length, relative clutch mass and neonate size is given. In addition, reliable longevity records have been supplied from species that have had the duration of their life in captivity. (*The Victorian Naturalist*, 134 (6), 2017, 199–200)

Keywords: Black Snake *Pseudechis*, husbandry, reproduction, longevity

Introduction

The genus *Pseudechis*, collectively known as Black Snakes, is an Australasian genus of elapids. There are ten species, nine of which are in Australia, with an additional species, *Pseudechis rossignollii*, restricted to New Guinea. The taxonomy of the group has been subject to numerous revisions and comments (Wells and Wellington 1987; Greer 1997; Hoser 1998; Wuster *et al.* 2004; Kuch *et al.* 2005; Eipper 2012; Hoser 2013; Cogger 2014). Further research is required before both the taxonomy and nomenclature of the genus are resolved conclusively. Currently, there are cases before the International Commission on Zoological Nomenclature that may have wide implications on the validity of the nomenclature proposed by some authors (Kaiser *et al.* 2013) and, therefore, pending the outcome of these cases, we are using the taxonomy used by Eipper (2012) and Cogger (2014).

Black Snakes are large terrestrial snakes with maximum adult sizes ranging from 1200 mm in *Pseudechis pailsei* to 3000 mm in *P. australis.* The basic husbandry of the genus is essentially the same for all species with the exception of *P. porphyriacus*, which requires a slightly lower temperature range. With the exception of *P. porphyriacus*, all *Pseudichis* are oviparous (Eipper 2012).

Husbandry

The snakes examined—*Pseudechis australis*, *P. utleri*, *P. colletti*, *P. guttatus*, *P. pailsei*, *P. porphyriacus*, and *P. cf. weigeli*—were maintained in terrestrial enclosures measuring 120 cm long, 45 cm high and 60 cm wide. Juveniles also were kept in plastic tubs measuring 80 cm long, 18 cm high and 45 cm wide, with underfloor heating. The enclosure temperature was approximately 27°C at the cool end, with a warm spot of about 31°C under the basking light/heating cable. *Pseudechis porphyriacus* was kept cooler with an enclosure temperature of approximately 26°C at the cool end and a warm spot of about 29°C under the basking light/heating cable. This species requires cooler conditions than other members of the genus because of a far more southerly distribution. A typical photoperiod matching outside conditions was provided. Suitable substrate included paper or compressed paper pellets. Juveniles were kept in conventional tubs, modified for snakes, until they measured approximately 60 cm in length, when they were transferred to adult housing.

Adult snakes were fed one or two small rats every two weeks, depending on the snake and size of the rat. Juveniles and yearlings were fed slightly more frequently. Some juveniles initially required scented rodents or an alternative diet of small fish. Snakes being fed fish or rodents initially required force-feeding or assistance in feeding. Fish were used as prey items because of their resemblance to lizards and frogs, the typical wild diet. Care was taken as the larger snake species can be cannibalistic in captivity (Eipper 2012).

The snakes required cooling from early May to late July. Male to female introductions oc-

curred from August to November. Males were moved in and out of a female's cage then rested for a few days. Male combat was observed.

Reproductive Data

Pseudechis australis clutch size ranged from 4–23, with an average of 12 eggs (n=6) per clutch. A clutch of 12 eggs was laid after a gestation of 41–48 days. Incubation took 79–81 days at 29–31°C. Hatchlings measured approximately 290 mm in length and 17.4 g in weight. Relative clutch mass (percentage of clutch weight compared to weight of the female post egg-laying) was up to 90%.

Pseudechis butleri clutch size ranged from 4–12 eggs with an average of 10 eggs (n=3). Incubation took 65–74 days at 28–32°C. I was unable to measure hatchlings, but Greer (1997) reported hatchling length to be approximately 276 mm.

Pseudechis colletti clutch size ranged from 7–18, with an average of 12 eggs (n=9). A clutch of 16 eggs took 69–72 days to hatch at 30–32°C. Hatchlings measured approximately 360 mm in length and 24 g in weight. Relative clutch mass was up to 86%.

Pseudechis guttatus clutch size ranged from 3–17, with an average of 13 eggs (n=7). A clutch of nine eggs took 68–70 days to hatch at 30°C. Hatchlings measured approximately 271 mm in length and 14 g in weight. Relative clutch mass was up to 83%.

A clutch size of five eggs has been recorded for *Pseudechis pailsei* but these eggs were not incubated (Hoser 1998).

Pseudechis sp. clutch size ranged from 6–11. One clutch of nine eggs was laid on 11 January. These eggs took 76–78 days to incubate at 30–31°C. The neonates were not measured.

Pseudechis porphyriacus litter size ranged from 5–23, but tended to average 15 young (n=4). Gestation ranged from 149–176 days. Neonates measured approximately 260 mm in length and 12.7 g in weight. It took up to 72 hours for the young to emerge from the embryonic sacs. Relative litter mass (percentage of litter weight compared to weight of the female post birthing) was up to 97%.

Longevity

We have been able to record the following longevity records within the genus:

- *Pseudechis australis*: 19 years, 6 months;
- *P. colletti*: 27 years, 4 months;
- *P. guttatus*: 22 years, 7 months;
- *P. pailsei*: 15 years, 1 month; and
- *P. porphyriacus*: 19 years, 6 months.

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Temperature and salinity effects on germination of three Victorian saltbushes (Amaranthaceae)

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Abstract

The effectiveness of coastal saltmarshes as carbon stores has been documented in a number of recent studies, and the vegetation that inhabits these systems is key to their high functionality. In this study, seeds of three common saltbushes were germinated under various temperature and salinity regimes to determine their sensitivity to conditions commonly associated with climate change. Seeds of Austral Seablight *Suaeda australis* had the highest germination success in more saline conditions. Germination rate and mean germination success of Seaberry Saltbush *Rhagodia candolleana* and Berry Saltbush *Atriplex semibaccata* consistently decreased with increased salinity stress. *Atriplex semibaccata* and *R. candolleana* experienced delays in germination in the lowest temperature treatment, and both were significantly affected by the interaction of increasing salinity and temperature. These results suggest that some saltbush species are more likely to persist in coastal systems than others in response to rising atmospheric temperatures and soil salinity as a result of climate change. (*The Victorian Naturalist*, 134 (6), 2017, 201–206)

Key words: Seed, regeneration, species distribution, saltmarsh, saltbush

Introduction

Recent studies have highlighted the importance of coastal systems in the efforts to combat anthropogenic climate change due to their capacity to store 'blue' carbon (carbon captured by oceans and coastal ecosystems) (da Silva Copertino 2011; Semeniuk and Semeniuk 2013). Vegetated coastal ecosystems, such as saltmarshes, are able to store up to 15 times more carbon per hectare and sequester carbon up to 50 times faster than comparable areas of terrestrial forest (da Silva Copertino 2011). Saltmarsh ecosystems, however, are in rapid decline, with 50% of the world's saltmarshes already lost (da Silva Copertino 2011). Saltmarshes are highly dynamic systems occupied mainly by halophyte vegetation that is frequently exposed to low hydrodynamic conditions and tidal inundation (Ungar 1991; Simas *et al.* 2001; Malcolm *et al.* 2003; Bellafiore *et al.* 2014). These ever-changing environmental conditions make coastal systems a valuable tool for formulating predictions of the potential impacts and risks of future climate change (Bellafiore *et al.* 2014). Already, studies by Rogers *et al.* (2014) have recorded dramatic changes in saltmarsh vegetation distribution as a direct response to rising sea levels, increasing temperature and elevated CO_2.

While most coastal vegetation is well adapted to the changing conditions of such an environment, plant tolerance of rapidly occurring climate change effects, such as increasing temperature and salinity, is not yet known. Previous studies found that halophytes can be sensitive to rapid changes in salinity, exposure time, and soil depth (Bellafiore *et al.* 2014). The current projections of an atmospheric temperature rise of up to 3°C by 2050, as well as rising sea levels, means that we can expect to see changes to soil depth and salinity of saltmarsh and, consequently, vegetation composition (Yirka 2012; Bellafiore *et al.* 2014). Although saltmarsh plants such as saltbushes (family: Amaranthaceae) have suitable adaptations allowing them to persist close to the shoreline, throughout the saltmarsh or more inland (Ungar 1991; Semeniuk and Semeniuk 2013), it is inevitable that these saltbushes will have a tolerance threshold when coping with increasingly saline soils and higher seasonal temperatures (Bellafiore *et al.* 2014). Differences in tolerance of these factors are likely to determine the spatial distribution of the vegetation across a saltmarsh as well as which species persist in changing conditions (Bellafiore *et al.* 2014).

This study aimed to assess the extent to which the interaction between salinity and temperature affects germination success in three saltbush species that occur in south-eastern Australia. It was predicted that *Suaeda australis* and *Atriplex semibaccata* would have the highest germination success under saline conditions due to their tendency to persist in the most saline soils (in close proximity to the shoreline as well as further away, in areas where mineral deposits have accumulated), whilst *Rhagodia candolleana* is generally less abundant in these areas. The combination of higher temperature and salinity was expected to inhibit germination in all species at varying levels.

Methods

Study species

Seeds of *Atriplex semibaccata*, *Rhagodia candolleana*, and *Suaeda australis* were collected in February 2015 from Jawbone Flora and Fauna Reserve, Williamstown on the southern coast of Victoria (Fig. 1). Seeds were cleaned, dried and stored until germination trials began in August 2016. All seeds were imbibed in distilled water for one hour then thoroughly rinsed to ensure naturally occurring germination inhibiters were removed prior to being placed under controlled study conditions (Ralph 1997). For scoring clarity, seeds were considered germinated when the radicle was visible, and germination was recorded every alternate day for 30 days.

Fig. 1. Seed was collected from the coastal saltmarsh of Jawbone Flora and Fauna Reserve in Williamstown, Victoria

Salinity and temperature effects on germination

Germination trials were carried out in 100 mm × 15 mm plastic petri dishes lined with Whatman filter paper (Grade 1) saturated in approximately 7 ml of test NaCl solution. Each dish was sealed with Parafilm to minimise evaporation. Five replicates of 10 seeds (of each species) were used for each NaCl treatment. Seeds were germinated in distilled water (0%), 0.5, 1.0, and 1.5% NaCl solutions under the following alternating temperature regimes: 5–14, 10–20, 15–24° C. These temperature regimes were selected to simulate mean seasonal temperature fluctuations of Williamstown, Victoria. During a 24-hour cycle, the higher temperatures coincided with a 12-hour light period and the lower temperature coincided with a 12-hour dark period.

Statistical analysis

Mean germination success, time to reach 50% germination (T_{50}) and time to first germination (lag), were calculated for each treatment. IBM SPSS statistical software was used to calculate a series of two-way ANOVA tests to determine if there was a relationship between temperature and salinity and germination success in each of the three species.

Results

Ragodia candolleana

Mean germination success in *R. candolleana* responded to temperature ($P<0.001$), salin-

Table 1. Mean germination success: *R. candolleana* was significantly linked to temperature, salinity and their interaction; *S. australis* was significantly linked only to temperature, and *A. semibaccata* was significantly linked to salinity and the interactions between salinity and temperature.

	Temperature	Salinity	Interaction
Rhagodia candolleana	P=0.000	P=0.000	P=0.000
Suadea australis	P=0.000	P=0.494	P=0.475
Atriplex semibaccata	P=0.644	P=0.000	P=0.026

ity (P<0.001) and the interaction between these two factors (P<0.001) (Table 1, Fig. 2a). The lowest temperature treatment produced significantly higher germination than the medium and high temperature treatments (P<0.001). All salinity treatments produced significantly different mean germination success, lag response and T_{50} (P<0.001) (Fig. 2a, b, c). Temperature alone did not affect lag response (P>0.05) but salinity and its interaction with temperature had a significant affect (P<0.05). Temperature, salinity and their interactions had an effect on T_{50} (P<005). Low and high temperature treatments did not produce significantly different T_{50} results, but the medium temperature treatment was significantly different from both the low and medium temperature treatments.

Suada australis

Mean germination success in *S. australis* responded only to temperature (P<0.001) (Table 1, Fig. 2d). All temperature treatments produced significantly different germination success (P<0.05). Lag response and T_{50} also were affected only by temperature, with the highest temperature treatment producing significantly slower germination than occurred at the low temperature treatment (P<0.05) (Fig. 2e,f).

Atriplex semibaccata

Mean germination success in *A. semibaccata* was responsive only to salinity and the interaction between temperature and salinity (P<0.001) (Table 1, Fig. 2g); but temperature influenced lag response and T_{50} (Fig. 2h,i). The higher concentrations of NaCl (1% and 1.5%) resulted in a significantly lower mean germination success, and significantly increased lag response and T_{50} (P<0.05).

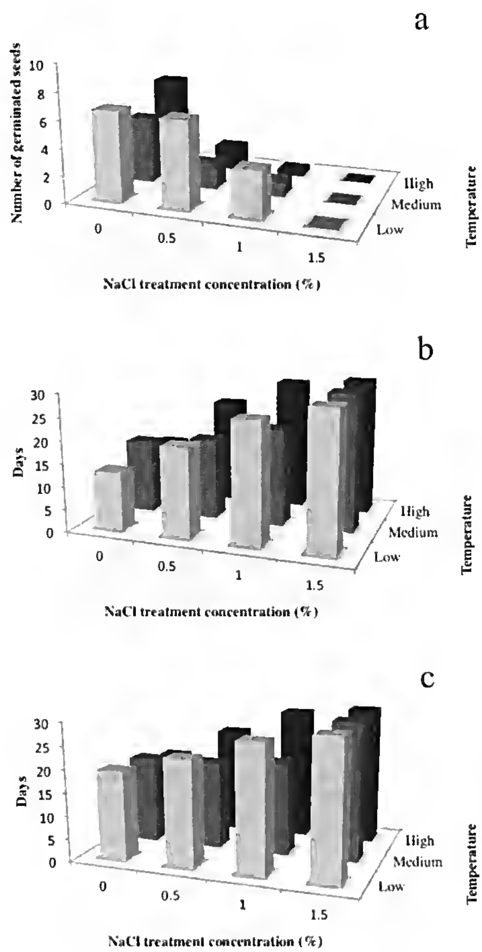

Fig. 2 a, b, c. Effects of salt and temperature on mean germination (a), mean lag response (b), and mean T_{50} (c) of *R. candolleana*.

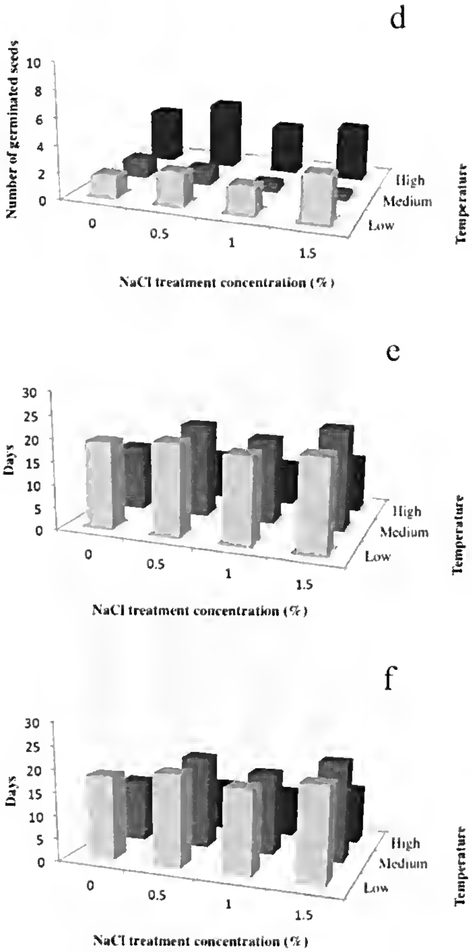

Fig. 2 d, e, f. Effects of salt and temperature on mean germination (**d**), mean lag response (**e**), and mean T_{50} (**f**) of *S. australis.*

Discussion

Increased salinity significantly affected seed germination of *R. candolleana* and *A. semibaccata* (delayed and/or inhibited), while differing temperature regimes significantly affected *R. candolleana and S. australis.* Responses of each species varied when simultaneously exposed to increased temperature and increased salinity, with *S. australis* alone achieving significantly successful levels of germination.

As with the work of Khan and Ungar (1984) and Khan *et al.* (2004), results suggest that a combination of environmental and biological variables, as well as interactions between these variables, can be responsible for either triggering or inhibiting germination to varying levels among saltbush species. Such environmental cues may be critical for the persistence of these species, enabling them to germinate only when ecological conditions are suitable to maximise the probability of successful establishment (Khan and Ungar 1984; Malcolm *et al.* 2003).

Rhagodia candolleana was the most sensitive of the study species; it responded significantly to both factors individually and to their interaction, resulting in poor germination at high temperatures and high salinities. This sensitivity to salinity extremes in particular may help explain why *R. candolleana* is deemed an uncommon component of most saltmarsh systems (Boon *et al.* 2011; Bull 2014; Atlas of Living Australia 2017).

Temperature alone had no effect on the germination of *A. semibaccata*, but increased salinities resulted in lower germination. Bull (2014) reported that *A. semibaccata* can persist in areas of high sun exposure but is salt tolerant only up to a certain point. It should be noted that *A. semibaccata* is currently the least abundant of the study species in the Jawbone Reserve and it is, in fact, rare in most saltmarsh systems Australia-wide, supporting the suggestion that salinity is more inhibiting than temperature (Boon *et al.* 2011). In areas where it occurs, *A. semibaccata* often is found in moderate to high densities, suggesting that it can thrive in saltmarsh but only where local conditions are suitable, i.e. up to a certain salinity (Boon *et al.* 2011; Bull 2014).

Germination of *S. australis* was the most successful under saline conditions, and only certain temperatures inhibited its success. Mean germination of *S. australis* was lowest in the medium temperature treatment (meant to replicate spring seasonal temperatures of the area) suggesting that, if anything, this species responds well to temperature extremes. *Suaeda australis* is the most 'mainstream' saltmarsh species in this study and is termed a 'structural dominant' of saltmarsh; this resistance to extreme temperature and salinity is a likely explanation for its success and

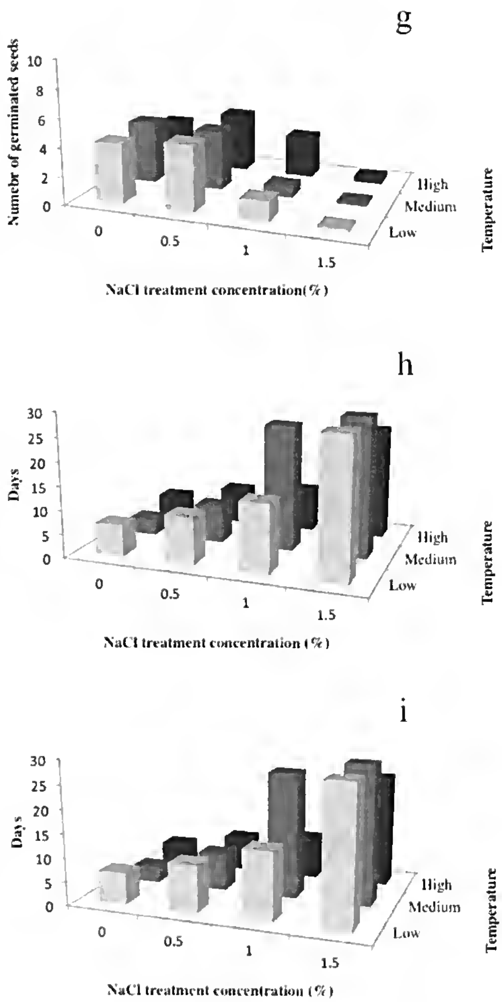

Fig. 2 g, h, i. Effects of salt and temperature on mean germination (**g**), mean lag response (**h**), and mean T_{50} (**i**) of *A. semibaccata*.

abundance in the Jawbone Reserve (Boon *et al.* 2011).

These results suggest that *R. candolleana* and *A. semibaccata* are clearly more vulnerable than *S. australis* to changes in temperature and salinity. This is to be expected as they are already marginal species in saltmarsh systems, whilst *S. australis*, as a dominant species, always was likely to show more resilience to saline conditions (Boon *et al.* 2011; Bull 2014). This species has adaptive leaf succulence, and is currently abundant across the saltmarsh with particular dominance close to the shoreline (Boon *et al.* 2011; Bull 2014; Atlas of living Australia 2017).

Conclusions

It can be concluded that temperature and salinity impact the germination of saltbushes, and that not all species are as resilient to changes in these climatic conditions as others (Khan *et al.* 2004). This could be of ecological significance as differing tolerances to salinity and temperatures may drive major changes to the distribution and composition of saltmarsh vegetation, which could have further implications for ecosystem functionality (Khan and Ungar 1984; Bull 2014).

Although previous studies have found that germination of halophytes can occur in a variety of salinities, many halophytic species favour conditions where NaCl concentration is less than that of seawater (600 mM) and require optimal temperatures for successful germination (Khan and Ungar 1984). It is therefore likely that increases in soil salinity and extreme temperatures (too low or too high) can induce seed dormancy, and may, in fact, inhibit germination completely in some species (Khan and Ungar 1984). Due to its preference for moist, saline soils and its resilience to extreme temperatures and NaCl concentration, it is likely that *S. australis* will persist as a 'structural dominant' of saltmarsh, whilst there is a risk that already marginal species such as *R. candolleana* and *A. semibaccata* will struggle to persist in the future (Bellafiore *et al.* 2014; Bull 2014).

The consequence of this is a trend towards homogeneity and therefore the loss of specific attributes held by certain species, such as an enhanced ability to combat soil erosion and offer storm protection, which help to preserve the whole ecosystem (Salmo *et al.* 2014). Given the known importance of these coastal systems to carbon capture, and the ensuing wider ecosystem benefits, it is vital that these systems maintain a level of species

diversity that gives them the best chance of remaining healthy and functional.

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Ninety-one Years Ago

EXCURSION TO TOORADIN

… The main feature of the shore vegetation at the mouth of the creek is White Mangrove, *Avicennia officinalis,* densely covering large area of tidal mud flats. No flowers, but some buds, and half-ripe fruits were found. Tooradin is the nearest place to the city where these curious plants may be studied. During a walk of two or three miles along the shore, many unfamiliar plants were met with, the rarest being Salt Plagianth, *Plagianthus spicatus,* which grew sparingly on the partially inundated sea-marsh land on which Samphire, *Arthrocnemum arbusculum,* Beaded *Salicornia australis,* Marsh Saltbush, *Atriplex paludosum,* Salt bush, *Rhagodia baccata,* and Trailing Jointweed, *Hemichroa pentandra,* were thickly interspersed.

On the drier parts the needle-pointed leaves of the Coast Speargrass, *Stipa teretifolia* (in fruit), were a menace to unprotected legs.

The most attractive feature of the saline-flats was the wealth of colour displayed by the Rounded Pig-face, *Mesembrianthemum australe.* The plant grew in large patches, often quite round, and the fleshy foliage varied from blood-red through pink and yellow to bright green, which, with the pink rays of the large flowers, made a gorgeous display. This was relieved by the occasional bright yellow patches of Water-Buttons, *Cotula coronopifolia.* In many of the patches of the Pig-face was a central mass of dead runners and leaves; outside this a zone of dead fruits with ripe seeds, then bands of colour, green, yellow, and red foliage, with the flowers on the last zone. They reminded one of Fairy Rings of fungi, and the same explanation, no doubt, would apply ...

H.B. WILLIAMSON

From *The Victorian Naturalist* **XLIII**, p. 244, December 7, 1926

King Island's lake of many names — Lake Flannigan: points of interest from the literature

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Abstract
King Island's Big Lake caught the attention of the Field Naturalists Club of Victoria in 1887, and it has continued to make occasional appearances in the scientific literature ever since. By assembling items of information from sundry sources over the last 130 years, a picture emerges, enabling an appreciation of the place of the lake in the natural history of King Island. (*The Victorian Naturalist*, 134 (6), 2017, 207–214)

Keywords: King Island, Lake Flannigan, Bass Strait Islands, Field Naturalists Club of Victoria.

Introduction

The Field Naturalists Club of Victoria (FNCV) has taken an enduring interest in the natural history of King Island. Seven years after the formation of the club, a nineteen-day field trip to the island was undertaken, from 3 November 1887. The naturalists followed in the fresh footsteps of surveyor John Brown, whose 1887 map (Brown 1887a) formed the basis of their own map of the island, and whose report to the Tasmanian Parliament was surely pored over when they were formulating their expedition plans (Brown 1887b).

The FNCV's observations resulted in notable scientific papers, published first in January 1888 in Volume IV, No. 4 of the *Victorian Naturalist*, an issue of the Club's journal devoted entirely to the findings of the expedition, and thereafter in both the scientific and popular literature. Since then, numerous individuals and groups have crossed Bass Strait to investigate the island. At the time of writing, July 2017, another FNCV visit to the island is planned for next October, to continue the quest for new data and the exchange of knowledge between local and visiting naturalists.

On the original 1887 trip, Big Lake (now Lake Flannigan) was visited by AJ Campbell and those who went with him to the north of the island (Campbell 1888b). Since then, the lake has proved to be of interest to a wide variety of people, including biologists, geologists, ecologists and aviators, as well as the people living on the island, including the school children (Fig. 1).

Nomenclature

In Tasmania the task of naming the country's physical features, such as mountains and lakes, is now the responsibility of the Nomenclature Board in the government department of Land Tasmania. This was not so in former times. As Smith (2006) observes:

> Until 1950 place names were applied by walking clubs and government bodies such as Mines Department, Hydro-Electric Commission and the Surveys Office. These names were loosely controlled by the Surveys Office, with municipal councils responsible for street, road and park names within township boundaries.

So it was that in 1887 different FNCV field parties assigned names to three of the island's places (Campbell 1888a). On 8 November, in the east of the island, Campbell and five others discovered a nameless rivulet two miles (3.2 km) north of Fraser River, which they named Spencer Creek, in honour of Professor Baldwin Spencer, a member of their party. The following day, Dudley Le Souëf and Spencer travelled south of Fraser River and, coming to the eastern-most bluff on the coast, they named it Point Campbell, after their expedition leader. Returning to the west of the island, on 11 November, Campbell and company worked their way north. Their guide, a hunter named Henry Grave, lived on the shore of the largest lake on the island, locally known as Big Lake. Appreciating it as 'a fine sheet of water', Campbell (1888a: 131) reported that they named it Lake Dobson: 'as a help to perpetuate the name of Dr. Dobson, who once filled the office of president

Fig. 1. Lake Flannigan, 2016, from the dunes on the western flank. Photo K Mather.

Fig. 2. Big Lake, 1887, photo AJ Campbell, courtesy FNCV. The name Lake Dobson was never officially adopted.

of this club, and who did much to contribute to the success of its expedition to King Island'.

Perhaps Campbell neglected to inform the Tasmanian Department of Lands and Surveys of the new names assigned during the FNCV visit, because their changes were never applied. By 1896, an official Lands and Surveys Department map prepared by the surveyor Michael John Flannigan, showed the rivulet as being named Eldorado Rivulet, not Spencer Creek; the bluff near the Fraser River was still nameless; and Big Lake's name was unchanged (Flannigan 1896a).

The permanent names of these places appeared to have been settled upon just after 1911, with Eldorado Rivulet having become Eldorado Creek, the bluff south of the Fraser River named Fraser Bluff, and Big Lake having become Lake Flannigan, to commemorate the young surveyor from Bendigo who had worked on the island and who died of tuberculosis in 1901 (Mather 2016; Anon 2017).

The Lands and Surveys Department's 1911 map, prepared by surveyor KM Harrisson, shows the name Lake Flannigan as written over the original name of the lake, which has been erased. This overwriting was regular professional practice at the time—lithographs had to give many years' service and were manually updated repeatedly until it was deemed essential to start afresh with a new lithograph. Thus it appears that the lake was still known as Big Lake when the map was first prepared in November 1911 (Harrisson 1911).

But by 1913 the new name 'Lake Flannigan' was officially in place, and the old name 'Big Lake' had been transferred to the previously nameless large lagoon to the south, in the Surprise Bay locality. Both lakes appeared in the *Tasmanian Government Gazette* of April 1913, designated as Game Reserves. (The Crown Lands Act 1911).

Palæontology and pedology

It was not only the naming of physical features on King Island that the FNCV expedition team broached, although other subjects sometimes waited many years before they could be addressed. During the 1887 visit, Spencer had noticed the presence of fossilised bones exposed by the shifting sands of the windblown dunes in the most southerly locality of Surprise Bay (Spencer and Kershaw 1910). He had regretted that there was no geologist with them on the trip and that no fossils could be collected at that time (Spencer 1888).

Eighteen years passed before expert attention became publicly focused again on the specimens from Surprise Bay. In 1905 one of the islanders, JM Bowling, presented the Surprise Bay bones to Queen Victoria Museum and Art Gallery, Launceston (Stephenson 1905). HH Scott, a curator of the museum, published his identification of Bowling's subfossils as *Macropus Anak* (Scott 1905), thereby sparking on-going controversy as to their identity and whether or not they were new to science.

After Scott's 1905 analysis, more scientists were attracted to the island and scientific writing flourished. In 1910, Spencer collaborated with Kershaw and listed bones found in the southern coastal sand dunes as belonging to a total of ten species, three of which were thought to be extinct members of the emu, wombat and quoll families. Spencer's terms for them were, respectively, *Dromaeus minor*, *Phascolomys ursinus*; and *Dasyurus bowlingi* (Spencer and Kershaw 1910). He did not provide common names.

In 1910, fossil marsupial bones were found in a different type of matrix—inland, in the Mowbray Swamp near Smithton, Tasmania. Debate intensified, with arguments for and against the likelihood that this member of the wombat family was *Nototherium tasmaniensis* or *Nototherium mitchelli* (Noetling 1911). On King Island, Lake Flannigan's neighbouring swamp, Egg Lagoon, further enriched the discussion in 1912 (Anderson 1914) by providing another *Nototherium* that curator Scott identified as *Nototherium victoria*, as reported at the time (*The Examiner (Launceston)*, 24 February 1912, page 6).

In the normal way of scientific scholarship, taxonomic categories are continually reorganised, and many of the original fossil-finds from King Island have since been reassigned to different species. The story of the classification of the King Island Emu *Dromaius minor*, for example, is well told in a publication by Queen Victoria Museum in Launceston (Green and McGarvie 1971).

It is conceivable that in 2006 Lake Flannigan could have provided more fossils, since the lake became dry and excavation would have been feasible. The lake was empty because of the impact of a year of extraordinarily severe drought (Bureau of Meteorology 2007) that intensified the effects of three decades of redirection of water from the Reedy Flats area into the ocean instead of into Lake Flannigan, as reported in the *King Island Courier* (Hunter 2006) (Fig. 3).

The interrelationship between Lake Flannigan and the former Reedy Lagoon area was understood and clearly shown on Flannigan's map of 1896 (Fig. 4). It is also noted by Jennings, who points out that the shoreline of the lake has changed markedly since 1896 (Jennings 1957). However, this knowledge had been lost over time, and had to be relearned from practical experience in 2006.

Fortunately, one of the landowners with property bordering the lake, Mr L Vivian, voluntarily ran a sustained and vigorous campaign to raise government and private funds for the remedy. During the campaign the Tasmanian Department of Primary Industries, Water and the Environment wrote to him as follows:

> Congratulations on successfully seeing the Community Water Grants project into the implementation phase, you have been diligent and inspirational in following it through. It must be quite devastating for you to see the lake nigh on dried up. But at least you now have money to redivert the drainage water back into the lake, so hopefully this will reverse the drying trend.
>
> (D Sprod, pers. comm. 27 March 2006).

The local newspaper followed the situation closely in its columns, and reported in August 2007 that, although water was flowing again into Lake Flannigan, Mr Vivian warned 'it will be quite a few years before the lake reaches its full capacity of two metres deep over an area of 150 hectares' (Hunter 2006).

Many years before, a CSIRO soil survey undertaken in 1932 had identified the soil types around Lake Flannigan, but not beneath it.

Fig. 3. Lake Flannigan in the drought of 2006. Photo Kathleen Hunter, courtesy *King Island Courier*.

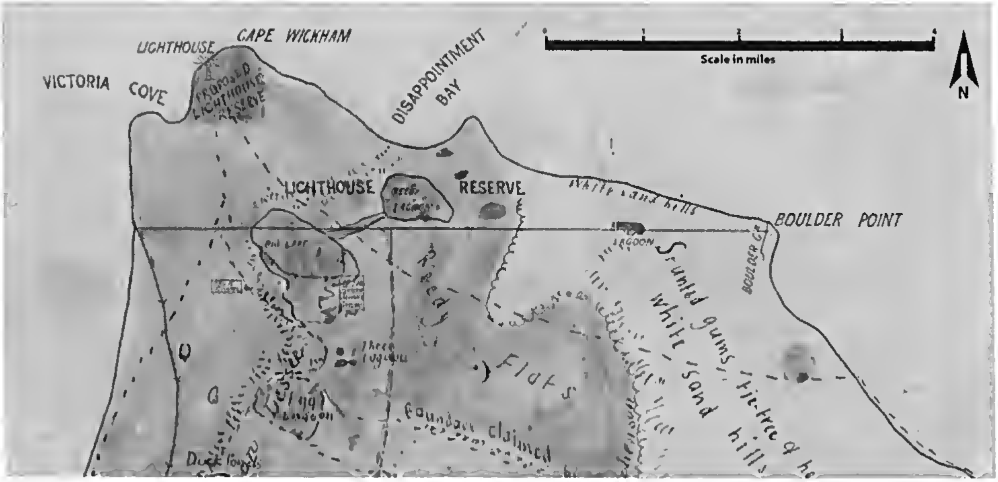

Fig. 4. Big Lake, 1896, and its main source, Reedy Lagoon (now drained). Detail from map by MJ Flannigan, courtesy LINC Tasmania State Archives.

West of the lake is 'Currie Calcareous Sand'; to the immediate north and south, Taroona Sand; and, to the immediate east, the Reedy Flat area is swamp soil, the same soil type as in the drained Egg Lagoon, where fossils were found in 1912 (Stephens and Hosking 1932). It therefore seems possible that the soil beneath Lake Flannigan is of the same type—swamp soil—and may also contain fossils.

Since there is no mention in the literature of visiting soil scientists or palaeontologists during the time of the dry lake, an opportunity may have been missed to bring Lake Flannigan into the island's palaeontological record.

Physiography

Geologist F Debenham (1910: 561) regretted that 'very little reference to King Island is to be found in the scientific literature'; since then, references devoted specifically to Lake Flannigan have been even sparser. In addition to its importance to agriculture, the lake is of ecological and social value, as will be shown below, so good data describing its physical attributes would be helpful in many ways. A summary of what can be gleaned from the literature is given here (Fig. 5).

Elevation, Area, Depth

Writing about the water bodies of King Island, JN Jennings (1957: 59) joined Debenham in wishing for more scientific data: 'the lack of soundings is particularly felt' and he was able to provide only approximations. He estimated the lake's elevation at about 50 feet (15.25 metres) ASL, and noted that the area and depth of the lake vary greatly depending upon the availability of fresh water from rainfall and from drainage from surrounding land such as Reedy Flats. Waves whipped up by the forceful winds of the Roaring Forties also change the shoreline. That said, Jennings (1957: 62–63) recorded the dimensions in 1957 as 'just over a mile [1.6 km] in meridional length and about three-quarters of a mile [1.2 km] in maximum width'.

In 2007 the local landowner L Vivian was reported as stating that the lake, when full, covered approximately 150 ha (Hunter 2006).

The two available estimates of the depth of lake vary significantly. To Campbell in 1887, the lake was 'surrounded by the usual swamp ti-tree, and has a depth of thirty feet.' (Campbell 1888b:155); 30 feet converts to 9.14 metres. By contrast, in 2007 L Vivian, speaking from experience as one whose land bordered the lake, estimated the normal depth as two metres (Hunter 2006).

Classification

Fresh water lakes are classified by limnologists as 'open', whereas lakes that become saline do so because they are 'closed'. As is shown above,

Fig. 5. Contemporary map of Lake Flannigan. Base image by LISTmap (www.thelist.tas.gov.au), © State of Tasmania

Lake Flannigan is 'open', with inputs of fresh water mainly from swampland to its east, and outputs underground through the dunes to the coast on its west. This throughput of water occurs because the basin of the lake is formed of a firm floor hemmed in by higher sand dunes of two types, through which the water is able to flow in and out. Jennings classified Lake Flannigan as 'a complex dune barrage lake type' (Jennings 1957: 64).

Protection

Flannigan was sent from Hobart to King Island in October 1895 to conduct a three-month survey of the island. In his report to the Tasmanian Surveyor-General, EA Counsel, one of his recommendations was that the shores of certain lagoons in the north of the island be given official protection from livestock. He had examined the soils, the landforms and the flora in the area and understood the interrelationship between the lagoons and their surrounds. He foresaw that 'if the frontages of these lakes [Bob and Egg Lagoons and Big Lake] are blocked by settlers it will be detrimental' to the balance of the country' (Flannigan 1896b: 3).

1913 brought an announcement in the *Tasmanian Government Gazette* that, under the Crown Lands Act, 1911, Lake Flannigan, Bob Lagoon, Porky Lagoon and the mouth of Yellow Rock River were reserved as sanctuaries for wild birds (*The Crown Lands Act 1911: King Island: sanctuaries for wildfowl* 1913).

In the twenty-first century, the protection for Lake Flannigan has been discussed again, during the 2005 process leading up to the *Crown Land Assessment and Classification Project Consultation Report and Recommendations Reservation of 20 parcels on King Island* report (CLAC Report 2005). The lake was classified as a Game Reserve, and permission was given for public access for the following activities: harvesting eels, duck shooting, fishing and camping. But the final decision was to hold the Game Reserve classification in suspension because:

> Access to water sources for stock was raised as an issue because of the lack of any real rivers or creeks in the locality and because sandy soils make dams impractical. It is recommended that the reserve not be proclaimed until, where there is no practical alternative, any necessary and suitable access points or arrangements, and

Fig. 6. Lake Flannigan, 1923, a photograph in the Leader (Melbourne). Courtesy of the State Library Victoria, Newspaper Collection.

> impact protection measures to allow for stock watering have been identified
>
> (CLAC Report 2005: 9).

More recently, the King Island Biodiversity Management Plan: 2012–2022 tabled Lake Flannigan as amongst the 'priority sites for management on King Island' because 'the largest patch of non-permanent foraging habitat for [the Orange-bellied Parrot] *Neophema chrysogaster* on King Island is Lake Flannigan' (King Island Biodiversity Management Plan 2012–2022: 129).

Aviation

In the words of twelve year old Mavis Batten, in her prize-winning essay of 1930:

> There are numbers of pretty spots all along the coast and many beautiful lagoons, hidden away in quiet places, fringed with dark scrub, which throws shadows across the still water, where black swan and wild duck find a quiet sanctuary. Lake Flannigan is well worth a visit. It may become a place of importance in the future, as a landing place for sea planes
>
> (Batten 1930).

Uncharacteristically, the lake frequently made news headlines in the *King Island News* from 1930 to 1933. Sailing to and from King Island had always been made exceptionally difficult by the forceful winds of the Roaring Forties coupled with the dangerously rocky coast. When, as reported on page 3 of the *King Island News*, 1 September 1926, an alternative to sea travel was spoken of by Senator Sampson, the islanders were keen to adopt it.

By early 1930, George Matthews, of Matthews Aviation Pty Ltd., had put forward a scheme to use Lake Flannigan as a seaplane landing site on a route from Hobart to Smithton, King Island, and Essendon Airport in Melbourne.

Every few months thereafter his fruitless attempts to track down soundings and other data of the lake were reported in the local press. By 1932, Matthews, the council and a local landowner had established another landing place on firmer ground, near Currie. By January 1933, Matthews suggested that the lake be considered only as an emergency landing site

should the aerodrome fail. The issue became irrelevant in May 1936, when one of Matthews' seaplanes made a forced landing in the sea at Currie, was violently thrown onto the rocks and wrecked. The passengers were unharmed, but Matthews lost heart, gave up the struggle, and sold his business (McDonald 2001). Lake Flannigan then returned to its former state of relative invisibility.

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The Australian Bird Guide

by Peter Menhkorst, Danny Rogers, Rohan Clarke, Jeff Davies, Peter Marsack and Kim Franklin.

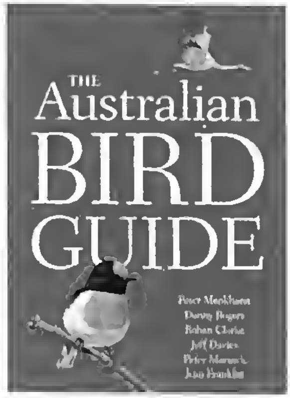
Publisher: *CSIRO Publishing, Clayton, Victoria 2017. 576 pages, Paperback. ISBN 9780643097544. RRP $49.95*

This book has been years in the making and has been eagerly awaited by the whole Australian birding community. It is the work of some of the most respected ornithologists and artists in Australia. Furthermore, data and photographs have been generously shared by many in the birding community, both in Australia and overseas, forming a vast archive of reference material for the 4700+ paintings that were created for the colour plates.

The aim of the authors was to produce the best bird guide in Australia, basing the structure and content on the best overseas guides. In my opinion they have achieved their objective.

Species are grouped according to the broad biomes in which they are most often found: marine, freshwater and terrestrial, indicated by colour tabs on the edge of the pages. Within those pages the birds are roughly in taxonomic order, but with some flexibility that allows similar birds to be grouped together. There is a visual quick reference on the two pages inside the front cover, an alphabetical quick reference to bird groups on page vi, and a full index of scientific and common names at the back of the book. This last index is useful only if you already know the scientific or common name, as it is sorted alphabetically by these names. For example, Black Falcon is listed under 'Black Falcon', not 'Falcon, Black' as in other field guides. If you are looking for a wattlebird then the bird group index is more useful.

One of the most startling differences from previous guides is the removal of overall length of a bird. This measurement is normally taken from dead birds that are stretched out, and so is not accurate for live specimens. Instead, the guide gives wing length, bill length and weight, as well as a scale on the colour plate to indicate length. All birds on each plate are drawn to that scale, unless otherwise indicated. I will admit it takes a bit of getting used to, but becomes easier with practice.



This book superbly addresses the range of plumages of the birds, as well as the subtle differences between subspecies. Range maps are at the bottom of the text page and show regular occurrence in darker colours, irregular occurrence in lighter colours and subspecies ranges in different colours. Coloured arrows are used to indicate small or island populations, with curved lines for post-breeding migration. Included on the heading line for each species is a circle that indicates likelihood of encounter, with abundant birds having a solid circle and very rare birds having only the outline of the circle.

There is a useful section on Birding in Australia that mentions when to go, migration, what equipment to use, ethical birding and documenting your records. There is also an excellent paper by Dr Leo Joseph on the evolution and classification of Australian birds.

The book has a ribbon bookmark that allows you to mark a specific page for quick reference. It is not a light book, weighing nearly 1.5 kg, so it unlikely to be carried in the field, but I consider this to be the sort of book one carries in the car as an excellent reference.

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Returning the Kulkyne

by John Burch

Publisher: *The Author 2017. Paperback. ISBN 9780646967523. RRP $29.95*
Copies available from returningthekulkyne@iprimus.com.au.

Returning the Kulkyne is an intimate portrait of the Kulkyne region of the Victorian Mallee, the region contained in what is now Hattah-Kulkyne National Park. Spring camping trips to Hattah Lakes as a child have left me with fond memories of huge skies, enormous red gums, kangaroos, goannas, waterbirds, red sandy soil and the endless solitude of mallee scrub. This is a special area, ecologically, historically and aesthetically, and John Burch clearly has a deep knowledge of the region as well as a profound interest and affection for this semi-arid northern corner of Victoria.

Although *Returning the Kulkyne* focuses on humans—Indigenous, farmers, conservationists, explorers, scientists, bureaucrats, recreationists and subsistence dwellers—the non-human environment suffuses and colours every chapter. Indeed, it is the interaction of humans with the physical environment of the Kulkyne that drives this story.

The book is organised chronologically within the three major themes of Indigenous people, agriculture and pastoralism, and protection—a structure that is initially confusing but allows for complexity in the historical account. Beneath the superficial structure of the book lies a narrative arc of human-environment interaction, beginning with pre-occupation, through degradation to partial restoration and, finally, turning to future conservation; it is the trajectory of this sub-plot that lends the book its name. Unlike more academic tomes, Burch seldom engages with broader environmental and conservation historiography, although he situates the history of the Kulkyne within broader historical themes of conservation, resource protection, settlement and colonisation. As he remarks in the foreward, this is a colonial, conservation, environmental and indigenous history.

Returning the Kulkyne is based upon extensive, detailed and exhaustive primary research in which Burch follows trails until they can

take him no further. He has tirelessly trawled maps, archives, newspapers, images and oral testimony as well as published documents, and it is the depth and breadth of this research that is the great strength and achievement of this book. Burch's detailed research thus reveals new and unusual stories that surpass many regional histories. One of my particular favourites is Burch's account of the Indigenous 'highway' that connected the Kulkyne with Wirrengren Plain within what is now Wyperfeld National Park. Another fascinating story is 'the white tribe' of hunters, fishers and subsistence dwellers who lived by the Lakes in the interwar years, many driven by a dearth of more conventional ways to earn a living. *Returning the Kulkyne* is a well-researched and often surprising history of a fascinating geographic region and a justifiable winner of the inaugural Victorian Premier's History Award in October 2017.

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Thank you from the Editors

The Victorian Naturalist could not be published, and would not be successful, without the tremendous effort given voluntarily by a large number of people who work behind the scenes.

As always, we particularly thank our authors, who provide us with excellent material for publication.

One of the most important editorial tasks is to have papers refereed. The Editors would like to say 'thank you', therefore, to the following people who refereed manuscripts that were published during 2016:

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The Victorian Naturalist publishes articles for a wide and varied audience. We have a team of dedicated proofreaders who help with the readability and expression of our articles. Our thanks in this regard go to:

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On the production side, thank you to:
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Guidelines for Authors – *The Victorian Naturalist*

December 2017

The Victorian Naturalist welcomes the submission of papers presenting original and significant research. When preparing a paper for publication, please follow the journal style as closely as possible.

Submission of a manuscript will be taken to mean that the material has not been published, nor is being considered for publication, elsewhere, and that all authors agree to its submission.

Authors may submit material in the form of Research Reports, Contributions, Naturalist Notes, Letters to the Editor and Book Reviews. All Research Reports and Contributions are peer reviewed by external referees. A ***Research Report*** is a succinct and original scientific paper written in a form that includes an abstract, introduction, methods, results and discussion. Research Reports should be written in third person. A ***Contribution*** may consist of reports, comments, observations, survey results, bibliographies or other material relating to natural history. The scope of a contribution is broad in order to encourage material on a wide range of topics and in a range of styles. This allows inclusion of material that makes a contribution to our knowledge of natural history but for which the traditional format of scientific papers is not appropriate. ***Naturalist Notes*** are generally short, personal accounts of observations made in the field by anyone with an interest in natural history. These notes also may include reports on excursions and talks, where appropriate, or comment on matters relating to natural history. ***Letters to the Editor*** must be no longer than 500 words. ***Book Reviews*** are usually commissioned, but the editors also welcome enquiries from potential reviewers.

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The following abbreviations should be used in the manuscript where appropriate (italicised as indicated): *et al.*; pers. obs.; unpubl. data; pers. comm. (followed by a date); 'subsp.' for subspecies.

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Leigh J, Boden R and Briggs J (1984) *Extinct and Endangered Plants of Australia*. (Macmillan: South Melbourne)

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Phillips A and Watson R (1991) *Xanthorrhoea*: consequences of 'horticultural fashion'. *The Victorian Naturalist* **108**, 130-133.

Smith AB (1995) Flowering plants in north-eastern Victoria. (Unpublished PhD thesis, The University of Melbourne)

Wolf L and Chippendale GM (1981) The natural distribution of *Eucalyptus* in Australia. Australian National Parks and Wildlife Service, Special Publications No 6, Canberra.

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Insects and Marine Creatures – ABRS: <http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/index.html>

Birds – Christidis L and Boles WE (2008) *Systematics and taxonomy of Australian birds*. (CSIRO: Collingwood, Victoria)

Plants – VicFlora (2015). Flora of Victoria, Royal Botanic Gardens Melbourne, <http://data.rbg.vic.gov.au/vicflora>, last accessed (insert relevant date).

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